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THE EFFECTS OF YOGA POSTURES AND BREATHING EXERCISES ON SELECTED PHYSIOLOGICAL PARAMETERS OF FEMALES

by

INDIRA SAROYA

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, thesis entitled "The Effects of Yoga Postures and Breathing Exercises on Selected Physiological Parameters of Females" submitted by Indira Saroya in partial fulfilment of the requirements for the degree of Master of Science.

Dedicated in memory of my Papa

a Karma Yogi

ABSTRACT

The growing popularity of Yoga and the paucity of evidence regarding its effects on bodily functions of the females prompted the need for an empirical investigation. The purpose of the study was to determine the effects of Yoga training on selected physiological parameters, which were relaxation, respiratory measures, and cardiovascular measures.

Twenty-three females (mean age 23.8 years) volunteered as subjects for this study. After the preliminary tests, they were randomly assigned to two groups, namely Yoga and control. The Yoga group was trained for eight weeks in selected *Asanas* and *Pranayama*, while the control group did not receive any training. The mid and post training tests indicated that certain significant changes had taken place as a result of training. In the Yoga group, significant decreases in frontalis EMG activity, resting heart rate, blood pressure and exercise heart rate at the 4th min., while increments in Vital Capacity and chest expansion were observed ($p < 0.05$). The control group did not show any significant change. Thus, the Yoga group individuals were more relaxed and improved in cardiovascular and respiratory measures as a result of *Asanas* and *Pranayama* training.

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DEFINITIONS

Asana: Its English translation is seat or pose. It is a static Yoga exercise or pose maintained for a specific period of time.

Bhujangasana: Its English translation is 'Cobra pose'. In this posture, the chest is fully expanded, the abdominal muscles are tightened, and the whole spinal region seems to be toned. (Fig. 1)

Dhanurasana: Its English translation is 'Bow pose'. It stretches the abdominal section of the body, and the muscles which flex the hip joints. (Fig. 2)

Halasana: Its English translation is 'Plough pose'. This posture stretches the whole spine. It strengthens the abdominal muscles. (Fig. 3)

Ardha-Matsyendrasana: In English it is known as 'Half-Spinal twist'. This posture is claimed to exert tremendous pressure on the liver and stomach. In addition, the pressure is applied to the kidneys and intestines. (Fig. 4)

Matsyasana: Its English translation is 'Fish pose'. In this posture the chest is fully expanded and breathing becomes deep. The thyroid glands may be stimulated due to the stretching of the neck. (Fig. 5)

Maximal Oxygen Consumption: The maximal amount of oxygen that can be absorbed by the cardiorespiratory system per unit time.

Paschimottanasana: Its English translation is 'Head to knee pose'. It claims to tone the abdominal organs and improve the spine. (Fig. 6)

Pranayama: Its English translation is 'Breath Control'. It is an element of Yoga involving a specific kind of respiratory control.

Sarvangasana: Its English translation is 'Candle pose'. It is known to have a beneficial effect on the metabolism of the body due to the stimulation of the thyroid gland from the pressure of chin against this organ. (Fig. 7)

Savasana: Also known as Shavasana. Its English translation is 'Corpse pose'. It is known to be a supine posture for relaxation. (Fig. 8)

Shalabhasana: Its English translation is 'Locust pose'. It seems to be a fine exercise for the abdomen, the hips, the pelvis and the lower back. (Fig. 9)

Submaximal Work Load: A workload which is within the limit of the adaptive potential of the cardiorespiratory system of the individual.

ABBREVIATION

BP	Blood Pressure
Cm	Centimeter
Dis	Diastolic
EMG	Electromyograph
HR	Heart Rate
Kg	Kilogram
l	Liter
Mid Trg	Mid Training Test
Min	Minute
Post Trg	Post Training Test
Pre Trg	Pre Training Test
PWC	Physical Work Capacity
Sec	Second
Sys	Systolic
VC	Vital Capacity
μv	Microvolt

CHAPTER I

STATEMENT OF THE PROBLEM

INTRODUCTION

Yoga is an age-old practice intended to satisfy the inner desires of ancient saints (74). From a secluded environment this system has become prevalent throughout the world.

Sanskrit word'Yoga'means yoke, which implies union with the Divine. A similar concept can be traced back to the word'religion.' It is derived from the Latin word 'Religio' which means to join. This term Yoga stands, first, for the correction of the human disharmonies into a harmonious unity, second, for the union of the human entity with God. According to Dalal (27),

> Yoga refers to a system of beliefs and practices whose goal is to attain a "union" of the individual self with Supreme Reality or the Universal Self. (P-156)

In the same way Aurbindo (11) defines the union of the individual soul with the universal soul as the aim of Yoga. Further, Singh et al.(74) stated that such a union could be attained only through complete subjection of the self to a rigorous discipline according to tradition based on countless centuries of experience.

There are five main ways of achieving this union. Each way has an ethical-religious system at the core and each sees the trance-like state of *Samadhi* as the final step in attaining union with Supreme Reality. As Manuvaryaji (54) states

> All Yoga is for the Divine - it is the conversion of the human soul into the Divine soul....... (P-3)

Although each of these Yogic paths is distinguished by its particular practices, they cannot be rigidly classified into watertight compartments. These systems of Yoga are:

a. *Jnana Yoga* or Yoga of Knowledge. It teaches to achieve a goal through wisdom and knowledge.

b. *Bhakti Yoga* or Yoga of Devotion. It emphasizes the role of love as the way to attain God communion.

c. *Karma Yoga* or Yoga of Action. It stresses the importance of work and duty in their pure forms, devoid of any desire for material profit.

d. *Raja Yoga* or Yoga of Self-knowledge. It aims at the development of man's full potential and expression of his inner spiritual self.

e. *Hatha Yoga* or Yoga of Health. It seeks primarily to correct physical and mental disharmonies through a balanced program of physical and mental training. Patanjali (5) in his Yoga Aphorisms refers to *Hatha Yoga* as modifications of the thinking principles which is obtainable through different methods such as controlling the vital breath and steady pose, both of which are intimately connected with the mind.

Traditionally, in this kind of Yoga there are eight limbs to follow to reach the state of *Samadhi*. These limbs are: *Yama* (moral restraints); *Niyama* (spiritual observances); *Pratyahara* (withdrawal of mind from external influence); *Asana* (bodily postures); *Pranayama* (regulation of breath); *Dharna* (concentration); *Dhayana* (meditation) and *Samadhi*(union with God). Out of these, the first five limbs constitute the outer phase of Yoga. *Yama*, *Niyama*, and *Pratyahara* are rules and regulations to govern the body through the mind; *Asana* and *Pranayama* govern the body and the mind. Whereas the last three limbs namely *Dharana*, *Dhayana* and *Samadhi* is known to be the final stage of mind and thus the final stage of Yoga.

Asana, *Pranayama*, and *Kriya* are the three forms of *Hatha* Yoga. However, *Asana* and *Pranayama* are popular in the western world. Their practice is popularized by rich bibliography and partially by some Yoga centres.

Asana is a Sanskrit term, which means a seat and implies steadiness and comfort. It requires relaxation and meditation on the immovable. In *Hatha Yoga, Asanas* include a wide range of physical and mental exercises, classified as stretching, inversion, balancing, standing and sitting postures.

According to Brena (21) *Asana* is a particular plastic attitude of the body and mind, through which certain muscular groups are put into action and vitalized. *Asanas* along with *Yama* and *Niyama* lead an individual to the threshold of super-consciousness. Wilson (98) observed that *Asanas* consist of slowly stretching and bending oneself in a particular position without strain or pain, holding the position for a length of time (10 seconds to 5 minutes or more) and then releasing the pose as slowly as it began. While holding a pose, awareness is integral to the area of stretch; its emotive and physical sensations are observed; the rest of the body is released from tensions; the breath is observed and regulated and awareness is focused on the infinite. Awareness of smooth regular, diaphragmatic breathing is integral to *Asanas* (5). These are not only for muscular development, balance and flexibility, but also to give vitality to the whole body. They are called postures because in each case the body bends or stretches into a special position for the free flow of nervous energy (98). So, *Asanas* are not exercises in movement.

There are numerous *Asanas* ranging from simple ones to very difficult, requiring a deal of strength, flexibility and control. According to the old legend, Lord Siva, the great Yogi, said that there are 8,400,000 postures (37). However, only about thirty-three postures are generally practiced as observed by Singh et al. (74).

Pranayama is an integral part of *Hatha Yoga*. In simple terms, *Pranayama* means energy control. It consists of special exercises involving inhalation, exhalation, and retention of breath. According to Vishnudevananda (91), the science of *Pranayama* starts with the proper control of the diaphragm and the respiratory muscles to bring a maximum degree of lung expansion and to absorb the greatest amount of life-giving energy from the air. Together with *Asanas* it keeps an individual physically and mentally fit. The other general effects of *Asanas* and *Pranayama* are described as clarity of mind, increased flexibility, muscular and mental relaxation, improved circulation and stimulation of the glands and skeletal muscles (72).

The interesting feature of *Hatha Yoga* is that no apparatus or equipment is required, and it can be practiced by males and/or females, individually or in a group. However, *Asanas* and *Pranayama* seem to be popular among women. Different authors recommend the practice of these exercises for females for reasons such as physical, mental and emotional fitness.

Sivananda (76) strongly urged women to practice as follows:

> Women should practice Yoga so that they will have healthy and strong children. If mothers are healthy the children will be likewise. The regeneration of young women means the regeneration of the whole world. Women who practice a course of systematically with interest and attention will have wonderful health and vitality. (P-23)

In view of the latter statement, a scientific study of females' participation in Yoga exercises would enhance the understanding of the effectiveness on the selected physiological parameters of females.

STATEMENT OF PROBLEM

The problem identified for the study was to examine the effects of eight weeks' Yoga training on selected physiological parameters using female subjects. The parameters examined were blood-pressure, chest expansion, degree of relaxation, resting heart rate and vital capacity. The secondary purpose of the present study was to investigate the Yoga training program's effect on the Exercise heart rates at the 4th, 8th and 12th min. as determined by submaximal tests.

HYPOTHESES

It is hypothesized that:

(1) There is no change ($p<0.05$) in the selected physiological parameters of females after Yoga treatment.

For both the groups:

$$H_o: \mu_c = \mu_t$$

where c = control, and t = treatment

(2) There is no change ($p<0.05$) in the exercise HRs (4th, 8th and 12th min.) determined by submaximal tests before and after eight weeks of the Yoga treatment.

For both the testing periods:

$$H_o: \mu_b = \mu_a$$

where b = exercise heart rates during submaximal test before the treatment started.

a = exercise heart rates during submaximal test after the treatment completed.

JUSTIFICATION FOR THE STUDY

In this modern world of technology, one is under tremendous physical and mental stress. According to Buzzard (23) one million working men's weeks are lost every year because of nervous disorders. The practice of Yoga is highly recommended to both males and females for physical improvement and mental

relaxation. Contrary to the popular belief, Yoga is not related to so called Yogic phenomena such as fire walking, the Indian rope trick, lying on nails or fire eating. Although, Yoga is based on empirical knowledge and there is nothing mysterious about it, there is a need for scientific investigation to clarify common misconceptions about it.

From time to time Yogis have been claiming the development of voluntary control over autonomic activities of the body. Regarding this Vivekananda (93) wrote the following:

> ...there is not a single muscle in the body over which man cannot establish perfect control by practice, even the heart can be made to stop or go at his bidding and in the same way each part of the organism can be made to obey him. (P-39)

Some studies have been done to evaluate scientifically whether Yogis can voluntarily stop the beating of their hearts (3,4). It has been suggested that the breathing and postural exercises may change the autonomic balance with possible effects on mental and physical health (96). These changes brought by some Yogic exercises appear to offer rewarding possibilities for further empirical investigations.

For centuries, the Yoga system was based on *Guru* to *Shisya* (master-to-disciple) instruction. The training was always comprehensive and complete. The influence of individual *Asanas* received no special consideration and the scientific basis of each pose was not investigated until Kuvalayananda (52) started his inquiry and inferred that particular *Asanas* produce particular effects. Based on his findings, he recommended a set of a few *Asanas* to meet present-day needs of busy people in term of time and convenience but Kuvalayananda's findings have to be assessed by further research. Yoga is considered as a systematic training program for all people regardless of age, sex and level of fitness. *Hatha Yoga*, as asserted by Vithaldas (92), would

> re-educate the abdominal muscles, buttocks and lumbars to resist the gravitational pull, keeping the body in a correct posture and intestines in the pelvic cavity. (P-16)

The Yogic exercises increase muscle strength and co-ordination, improve flexibility of the trunk and extremities, help develop grace and poise of the entire body, reduce nervous tension and establish a sense of well-being (78).

Some studies (33,83) show that Yoga exercises result in an increase in the chest girth, higher degree of relaxation, decrease in resting heart rate and very little or no improvement in the physical work capacity. These findings need further confirmation due to conflicting results.

The effects of Yoga are indeed of special interest to exercise physiologists. Govindarajulu (43) urged that literature on the subject is hardly scientific and though there is a great deal to be said in its favour, one has to move with caution. Day (32) affirmed that extravagant claims made about Yoga postures should be accepted with reserve. It is, therefore, obvious that there is need for scientific proof concerning the effects of Yoga training.

Mookerji et al. (59) trained the Indian field hockey team (winners of Third World Cup, 1975) in some Yoga exercises and attributed the success of the team partially to these exercises. According to the researchers, the *Asanas* improved the degree of relaxation and hence, overall performance of the players. Mayol (56), the world record holder in breath-hold diving also stated that he practised Yoga regularly. In view of such claims made about the efficacy of Yoga as being contributary in the athletic skill and work capacity, there is a wide spread interest and curiosity in regard to Yoga among the research-minded people. Although the field of Yogic practices has not been sufficiently explored, whatever little work has been done indicates that these practices might make a significant contribution to physical education.

Dhanaraj (33) did an experimental study in which the subjects of Yoga group had to follow a schedule of *Asanas* and breathing exercises. The investigator observed positive effects of Yoga training on the physical fitness of males.

It is necessary here to point out that almost all of these studies were done on male subjects. Inspite of Yoga's enormous popularity among women, very little or no experimental research has been done on them. Thus, women are important subjects to study the effects of Yoga postures and breathing exercises.

In the present study, the Yoga training group had to follow a schedule of certain *Asanas* and breathing exercises. The *Asanas* were so selected as to effect the chosen parameters of general physical fitness. Mostly these *Asanas* were part of a Yoga training program in different studies (42,82). The order in which *Asanas* were performed was chosen to balance the directionin which one was moving. Execution of the posture was interspersed with short periods of relaxation, in which the practitioner concentrated inwards. During the Yoga exercises the subjects were asked to concentrate on muscle groups involved as this would seem to affect nerve stimuli and consequently cause physiological changes. To keep the mind calm and increase the concentration a short period of silence was included in the

beginning of the training session. The subjects were asked to maintain their normal routine of living, in order to secure conditions of participation similar to those in western environment.

The lack of information regarding the effect of Yoga training on the physiological parameters of females provided a justification for this study. The effects of Yoga on females would be of special interest to exercise physiologists. It, therefore, was imperative that a scientific study in the field of *Hatha Yoga* pertaining to females be done. A study of effects of the Yoga on physiological parameters might reveal some interesting facts. With this in view, the parameters of physical fitness, namely resting heart rate, blood-pressure, degree of relaxation, exercise HRs (4th, 8th and 12th min.) as determined by submaximal tests and chest expansion were studied. The study has thus a purpose of determining the effects of Yoga training by comparing the measurements so obtained on different parameters with control. Another purpose of the study was to see the rate of improvement of physiological parameters within eight weeks of Yoga training.

Thus, the present study should be useful in extending the knowledge in the area of Exercise Physiology.

LIMITATIONS OF THE STUDY

1. Though the subjects were asked to maintain their normal pattern of life including physical activity, no control was imposed on them.
2. The study was limited by the individual ability of each subject to understand and follow the instructions relative to training and testing.
3. No control was established on the ability of the subjects to concentrate on a single thought.
4. The possible errors in testing procedures might have led to the limitation of the study.

DELIMITATIONS OF THE STUDY

1. The study was limited to 27 female volunteers aged 17 to 29 years.
2. The training program consisted of 9 *Asanas* and 2 *Pranayama* exercises.
3. Each training session was held for forty minutes a day, three days a week for eight weeks.

CHAPTER II

REVIEW OF THE LITERATURE

HISTORY OF YOGA

Yoga was developed in ancient days as a spiritual discipline, but its history is obscure. Although it is known that Yoga originated in India, no one knows exactly when it came into existance. In the absence of authentic records, it is surmised that Yoga is about 5,000 years old. The philosophy of Yoga is discussed in details in Bhagavad Gita (39) and Upanishads (66).

It seems Yoga is a slowly developed, body of knowledge, transmitted from generation to generation through the teachings of enlightened masters, known as *Rishis*. The earliest text available on Yoga is Yogasutras of Patanjali (5) which is dated about 200 B.C. Yogasutras consists of 185 aphorisoms and describes the definitions, philosophical thoughts and directions for practice of Yoga. Among the other texts on *Hatha Yoga* available today, the best known are the *Hatha Yoga Pradipika* (75) *Siva Samhita* (90), and *Gheranda Samhita* (89). These are in Sanskrit and have been translated into many other languages. These translations should be read carefully as the meaning of some original scripts might have changed. These texts deal with various disciplines and practices of *Hatha Yoga*. As claimed by

their authors, extraordinary physical and mental powers could be attained by Yoga practices. Often there are references of great spiritual achievements following the practice of Yoga regularly. This leads one to believe that the Yogis were interested not only in the physical aspects but also aspired for the spiritual unfoldment through it.

Traditionally Yoga training was a long procedure controlled and handled by the *Guru* or Master who tutored and watched the *Shishya* or disciple strictly according to individual needs. The selection of exercises and the intensity of training were left entirely to the discretion of the *Guru*. The *shishya* was expected to be regular and dedicated. He incorporated Yoga into his daily life chores to ensure progress. The outcome of such a long-term training was subjectively evaluated by the *Guru*. The *Guru-shishya* system is vanishing and being replaced by group instruction.

The term Yoga, in its common usage, has been associated with *Asana* (physical postures) and *Prayanama* (regulation of breath). An individual who merely practices the postures and breathing exercises without following the other six limbs is not practising Yoga in the strict sense. According to Kuvalayananda (52), *Asanas* were practiced by the Yogis to enable them withstand the strains of prolonged meditation and direct the spiritual forces when aroused.

These days *Hatha Yoga*, especially *Asanas*, are becoming increasingly popular in the western world. It is surprising that an original system is being adapted by the modern pace society. Men and women of all ages seem to be fascinated by Yoga exercises. Women take Yoga classes to keep them healthy and happy. Iyengar (48) reported that *Asanas* help in remaining young, flexible, strong and vital.

Yoga has lately been introduced in sports to improve the athletic skills and work capacity. Mookerji et al.(59) attributed the success of Indian field hockey team (winner of the Third World Cup, 1975) to Yogic exercises. According to the researchers, the introduction of *Asanas* in the training was one of the deciding factors in the success of the hockey team as it improved the level of relaxation and self-confidence in the players. Further Mayol (56), who held the world record in breath-hold diving, said in a press interview that he practiced Yoga regularly.

The recent interest of the people from all spheres in Yoga has drawn the attention of scientists. Attempts to describe Yoga philosophy and theory of personality in physiopsycology are being made with greater frequency (1). Relaxation and meditation components have also received an increasing attention during last decade, and along with biofeedback they encompass a large body of literature in their own right (73).

Investigations into the effects of Yoga practices have been made in fields as diverse yet interrelated as health and fitness (72), medicine (46), physiology (83) and Psychoanalysis (20).

PHYSIOLOGICAL EFFECTS OF YOGA

RELAXATION

Human mind and body is under tremendous stress in this modern era. The condition or state of stress is not merely discomfort, that is increased muscle tension, perspiration, rapid and shallow breathing, increased heart rate, etc - in sum readiness to flee or to fight. What is of much greater significance are the possible consequences of this interaction and response - poor health and certain disease. There is even a possibility of as much as 75 percent of all illnesses being stress related (62). Yoga helps to reduce stress by achieving integration, that is a state of homeostasis indicating a stable equilibrium of internal functions (7).

Although *Savasana* is a special Yoga technique of relaxation, all *Asanas* tend to induce a quiet state characterised by apparent relaxation. Armstrong (6) stated that regular practice of Yoga helps to attain 'supreme physical relaxation'. Mclanhan (57) has described Yoga practice as an 'antistress tablet' that helps people to avoid anxiety and depression. In their report, Digamberji et al. (35) stated that the regular practice of Yoga improves the capacity to relax physically and mentally. The

postures have an influence on balancing the autonomic nervous system that creates a calmer, less anxious physiological environment. There is also a reason to assume that fewer psychosomatic complaints are manifest in regular Yoga practitioner due to the direct manipulation of the muscles and viscera, the ANS balance, and the decreased anxiety (7).

Asanas, especially *Savasana*, as reported by Mclanahan (57), are useful to relax the tense muscles and released the 'bottled emotions'. According to ancient claims (75), one should be able to achieve tranquility and peace through the practice of *Savasana*. Wilson (98) described *Savasana* as follows:

> When the resting is consciously cultivated in supine position while maintaining diaphragmatic breathing and calm mind, it is called *Shavasana* or 'corpse' pose. The name is associated with the 'ultimate relaxation of death. (P-261)

The practice of *Savasana* is a systematic technique and not just allowing inertia or inactivity to take over. During its practice, heart rate and respiratory rate are minimum and peripheral blood flow is almost maximum (41). These findings indicate a relaxed state of body and mind during this posture. Anand and Chinna (3,4) reported the intensification of α-waves during *Savasana* in Electroencephrlographic recordings. It cannot be compared with the state of sleep which results in accummulation of carbondioxide and lactic acid in muscles (57).

Datey et al. (28) studied the effects of *Savasana* on 47 hypertensive patients with blood pressure in the range of 160 - 279/90 - 145 mm. of Hg. The patients were divided into three following categories: (a) Those on no medication; (b) Those whose hypertension was controlled by drugs and (c) Those whose hypertension was not adequately controlled by drugs. They practiced *Savasana* thirty minutes daily for three months. For those not on medication, blood pressure reduced by an average of 27 mm. of Hg in 7 out of 10 cases. In the second group, the effect of *Savasana* training was evaluated in terms of the reduction in patients drug dosage required to bring their blood pressure under control. The drug dosage decreased by 33% or more for 13 out of 22 patients. In the third group the effects were evaluated in the same fashion and drug dosage reduced by 33% for 6 out of 15 patients. The investigators also reported that nervousness, irritability and insomnia disappeared in almost all the patients.

Patel (64) reported a significant reduction in blood pressure of 34 hypertensive patients who practiced Yoga and biofeedback. They reported an average reduction of 27 mm. of Hg in systolic and 16 mm. of Hg in diastolic blood pressure after a six week training period. Patel (63) further found an average reductions of 20.4 mm. of Hg in systolic and 14.2 mm. of Hg in diastolic blood pressure at the end of nine months (three times a week) training among 20 subjects. As a result of these treatments,

antihypertensive therapy was stopped altogether in 5 patients. Blood pressure control was found to be improved in all the patients. Further, these studies showed that a short training program in Yoga does have clinically significant effects on a majority of the hypertensive patients.

Dhanaraj and Singh (34) studied the physiological effects of Yoga on three groups of seven normal males. One group received a twelve week class with Yoga postures and *Savasana*. The second group practiced TM, and the third group received no treatment. At the end of the treatment period, data were collected after a fifteen minutes period of resting in a chair and again after each group practiced their respective treatments (*Savasana*, TM and reclining in a supine position). Sleep was controlled for. Pretreatment and post treatment values showed a significant decrease in oxygen consumption for all groups (Yoga = 10.3%, TM = 15.5%, Control = 3.5%) indicating general relaxation. Such a change is likely to bring about many other ANS changes as well.

Karambelkar et al. (50) studied the effect of *Asanas* on two groups of seventeen subjects each. Significant decrease in muscle activity in the buttock and calf occured as indicated by EMG measurements,as subjects relaxed into the pose. Grossbach (44)

using GSR and EMG biofeedback reported that prisoners trained in physical postures learned to relax significantly quicker than prisoners without such training. Udupa and Singh (84) observed a prominent alpha wave pattern with fewer spikes during EEG measurements of the subjects practising Yoga thus reflecting a less irritable nervous system. In a similar study Udupa et al. (85) found decrease in plasma acetylcholine and serum cholinesterone, the metabolic indices of anxiety, among the subjects. Recently Tulpule and Tulpule (82) did a study on 102 Myocardial Infarction patients. Of the trial group, 96 patients were able to resume work within 6 months of Yoga practice indicating a great decrease in mortality rate. The investigators concluded that *Asanas* bring about relaxation and hence, help in achieving the results.

CARDIOVASCULAR FITNESS

Digambarji (35) reported that school children trained in Yoga for six weeks showed signs of improvement in cardiorespiratory efficiency and athletic ability. Ganguly (38) trained eleven male subjects for eight months. The training program was of Yogic practices including *Asanas, Pranayama, Bandas* and *Mudras*. During the training period, subjects did not engage in any vigorous exercise except the training schedule prescribed for them. The post training tests indicated a significant improvement in cardiovascular efficiency. Contrary to the above reports, Gharote (40) did not observe any significant

improvement in cardiovascular efficiency as measured by Harvard step test in a study of 49 males (mean age 19.7 years) trained for nine weeks. Harvey (45), on the basis of his personal experience, stated that the regular practice of *Asanas* improves flexibility, increases muscular endurance but deteriorates cardiovascular efficiency. Romanowski et al. (71) examined trained Yoga Practitioners to determine their ability to perform endurance exercises. The subjects found it hard to manage a work load which was moderate for others trained in sports. However, the oxygen debt suffered by the Yoga Practitioners was smaller and their recovery from fatigue was faster. The researchers attributed this partly to their mastery of relaxation. Rao (69) determined the metabolic cost of *Sirshasana* (described as the Topsy-turvy Pose or Head-stand) using 6 male volunteers aged 19 to 22 years, as subjects. The amount of O_2 consumed during the exercise was found to increase 48% above the value obtained in standing position, indicating that *Sirshasana* is a light form of muscular exercise. This observation suggests that the energy cost of *Asanas* is rather low, and for this reason, *Asanas* cannot be regarded as endurance exercises. *Asanas* may be normally regarded, for the same reason, as non-fatiguing activities.

Although the improvement of cardiovascular endurance by Yoga exercises is controversial, it is well established fact that the resting heart rate is lowered with the practice of *Asanas* and *Pranayama*. Wallace (94) reported significant decrease in meditators' heart rate during and after the practice of Yoga. Wenger et al. (96) demonstrated slowing of the heart rate and pulse in Yogis and proposed the mechanism to be resulting in a strong increase in vagal tone of unknown origin. However, none of these researchers made any comparative study.

Datey (28) reported that *Shavasana* probably influences the hypothalamus through continuous feedback of slow, rhythmic proprioceptive and interceptive impulses and tends to set it at a lower level in reducing blood pressure. Udupa et al. (86) trained six male volunteers (mean age 22 years) in breathing exercises for six months. The tests following the training indicated that subjects' mean resting heart rate decreased from 65.2 to 61.0 beats per minute. In a similar study on 12 males, Udupa, et al. (85) observed a decrease in mean heart-rate from 66.6 to 62.2 beats per minute. In the comparative study (87) of two different groups practising Yoga, the investigators noticed that six months training in *Shirshasana* (head stand), *Bhujangasana* (cobra pose) and *Mayurasana* (peacock pose) helped the most in decreasing the resting heart-rate. On the contrary, the practice

of *Sarvangasana* (candle pose), *Matsyasana* (fish pose), *Halasana* (plough pose) resulted in a minor decrease in the resting heart-rate. Dhanaraj (33) observed a significant decrease in the mean resting heart-rate (72.5 to 62.0 beats per minute) of 15 young adults who trained for six weeks in *Asanas*. He concluded that Yoga does not promote cardiovascular fitness but enhances the general efficiency of the heart. Bagga and Gandhi (12) concluded in their study on 18 subjects that *Shavasana* lowers the heart rate and blood pressure.

CHEST EXPANSION

In one of the foremost longitudial studies on the effects of *Asanas*, Udupa, et al. (83) reported the observations made on 12 males (mean age 23 years) trained in breathing exercises for six months. After the training, the investigators found that the average chest expansion of the subjects increased from 3.4 to 4.3 cm in the first three months, and from 4.3 to 4.7 cm in the next three months. Later on, Udupa et al. (85) observed that the chest girth improved significantly with *Sarvangasana* (shoulder stand) and *Shirsasana* (head stand), while *Halasana* plough pose) had the reverse effect. Day (32) indicated that an increase of 7 cm or more or chest expansion had been claimed by those who specialize in a Yoga type of breathing exercise. A significant increase ($p<0.05$) of 1.8 cm in the mean of chest expansion was observed by Dhanaraj (33) as a result of Yoga exercises for a period of six weeks. This increase as a result of *Asanas* and *Prayanama* was more than that of the 5 BX exercise plan. Nayẹr et al. (61) established the fact that breath holding time can be significantly increased by yoga exercises.

VITAL CAPACITY

In an extensive study on 147 teachers (aged 18 to 50 years) lasting for four weeks, Bhole and Karamblker (18) found that the mean Vital Capacity increased from 3.4 to 3.6 liters. Udupa et al. (87) reported that the average Vital Capacity of 12 young male subjects increased significantly (3.7 to 4.6 l) within 6 months of Yoga practice. A mid training test indicated that Vital Capacity increased from 3.7 to 4.3 liters within 12 weeks. In another study Udupa et al. (86) observed that the Vital Capacity of six male subjects (mean age 22 years) did not alter significantly (4.1 to 4.3 l) with breathing exercises for six months. Nayer et al. (61), while conducting a study on 53 cadets of National Defence Academy of India observed an improvement in the Vital Capacity as a result of Yoga training along with normal Defence Academy training. Dhanaraj (33) found a significant improvement in Vital Capacity (4.3 to 4.8 l) for15 male subjects (mean age 18.8 years) trained for six weeks in Yoga exercises.

CHAPTER III

METHODS AND PROCEDURES

SUBJECTS

Twenty seven female students and employees of the University of Alberta volunteered to be the subjects in this study. Their age ranged from 17 to 29 years and the mean was 23.8 years.

EXPERIMENTAL PROCEDURES

ORIENTATION

The orientation meeting was divided into three phases. The first phase was to fill in a questionnaire (Appendix A). The subjects were asked to complete the questionnaire concerning their state of health, participation in physical activities and other habits. The purpose of the questionnaire was to ensure that the subjects were not participating in any vigorous physical training, were beginners in Yoga, were free from organic diseases and were not under any medication. The second phase of the orientation was to familiarise the subjects with the study. A brief talk was given to them regarding history, philosophy and modern trends of Yoga. The subjects were also acquainted with the purpose of the study, the training program and the testing procedures. The third phase of the orientation was a short tour to the laboratories. Testing procedures were explained to all the subjects. They were then given adequate time to observe and understand the working of the

apparatus used in the tests. This procedure was followed for the proper understanding and co-operation of the subjects. To minimize the effect of other variables, the subjects were asked to maintain their current physical activity and diet pattern. They were also instructed not to smoke, not to take heavy meals and not to engage in a strenuous physical activity two hours prior to the testing sessions, as all these three factors might affect the results.

APPARATUS AND THEIR CALIBRATION

APPARATUS

The apparatus and instruments used for testing included cardiotachometer, Collins Standard Vitalometer, Honeywell Electronic Medical System, Model 250 EMG Integrator, Monark Bicycle Ergometer, measuring tapes, sphygmomanometer and stethoscope, stop watches and weighing scales.

CALIBTRATION

All the apparatus and instruments were calibrated and checked for precision in the beginning of the experiment and before each testing period. The Monark Bicycle Ergometer was calibrated according to the standard procedure. The EMG machine was calibrated with the assistance of the laboratory technician, according to the standard procedure given in EMG manual.

ACCESSORIES

The accessories pertaining to the apparatus and the instruments used for testing included surface electrodes, electrode jelly and nose clamps. All accessories were carefully checked to ascertain accurate measurement.

LABORATORY TESTS

In order to observe the rate of improvement and to evaluate the significance of the treatment, each subject was tested on three different occasions. The different testing periods were entitled as follows:

Test 1 (T_1)	Pre-training Test	Before treatment
Test 2 (T_2)	Mid-training Test	After fourth week
Test 3 (T_3)	Post-training Test	After eighth week

On each occasion, the tests were done at the same time of the day and under the same laboratory conditions. The temperature of the laboratory was maintained at $20 \pm 1^{o}C$ during all the tests.

After post training tests, the subjects were required to complete another questionnaire (Appendix A) which would help the researcher to make a subjective analysis of the effects of training.

The order of testing was as follows:

Serial No.	Test
1.	Height and Weight
2.	Chest Expansion
3.	Resting Heart Rate
4.	Blood Pressure
5.	Relaxation
6.	Vital Capacity
7.	Physical Work Capacity

DESCRIPTION OF THE TESTS

HEIGHT AND WEIGHT MEASUREMENT

The height and weight of each subject was obtained during this test. The data were derived using standard laboratory equipment and procedures.(25)

CARDIOVASCULAR MEASURMENTS

RESTING HEART RATE

The resting HR of the subject was measured in a lying position with a cardiotachometer. To obtain the resting HR of the subject, one of the recording electrode was placed over the midsternum, second over the fifth rib and the ground electrode was put halfway between those two. The electrodes were firmly attached with a strong adhesive. It was observed by Pope (65) that when the elecrodes are properly attached the cardiotachometer gives reliable recordings.

EXERCISE HEART RATE AND PREDICTED OXYGEN CONSUMPTION

During this session, the subject was closely monitored while she was pedalling the Monark Bicycle Ergometer. The objective of this test was to observe HR changes throughout the period of increasingly difficult work load. Therefore exercise HRs at increasing work load over a period of 12 min. were determined. For this test modified Sjostrand PWC 170 protocol was used. Before administering the test, the subject's weight was measured. The subject mounted a Monark Bicycle Ergometer and the seat was adjusted to a height which allowed a slight bend in the knees with the pedal at the bottom. The initial HR was noted and time was allowed till normal resting HR was established. The subject was required to pedal at 60 RPM in cadence with a metronome set at 60 beats per minute for a total timing of twelve minutes. This twelve minute period consisted of three four-minute rounds of progressively increasing work loads, so adjusted as to induce a HR of about 180 during the third phase of the exercise. The HR was recorded with the help of a cardiotachometer at the end of the 4th, 8th and 12th min. The work loads for the Pre Mid and Post test were same. The purpose of this test was to asses a subject's ability to work at HRs of 130, 150 and 170 b/min. during the 4th, 8th and 12th min. of work on a Monark Bicycle Ergometer. The work load was calculated and plotted against HR only during the last min. of each work interval as then the subject attained steady state HR. A predicted value of maximal O_2 consumption was calculated from the nomogram (8).

RELAXATION

FRONTALIS EMG

During this test, the degree of relaxation of the subject was measured as electromyographic recording of the frontalis muscle. While many recent investigators have agreed that EMG is a reliable devise to measure muscle tension (14,15,22), yet the disagreement still exists regarding the muscle groups of which recordings are to be taken. However, the frontalis muscle is popularly used to measure relaxation in clinical studies. In the present study the frontalis muscle was chosen since it is less affected by posture and gravity than most of the other muscles. In addition, the frontalis muscle is difficult to relax voluntarily and frequently remain tense in anxious subjects (16). The wide application of frontalis EMG biofeedback training rests on the important assumption that lower levels of frontalis EMG training can produce generalized body relaxation. There are two sources of basic research evidence that bear on this assumption: (a) studies that have examined the relationship between frontalis EMG activity and EMG activity in other muscle groups; (b) studies that have examined the relationship between frontalis EMG activity and subjective report of relaxation (14,22).

The electrodes were placed on the frontalis muscle in the conventional manner as described by Davis et al. (29). Three silver chloride surface electrodes were placed across the frontalis muscle approximately one inch above the eyebrow and two inches lateral to

the midline. This arrangement measures EMG from the outer two electrodes using the central electrode as reference. Resistance between any pair of the three electrodes was always below a maximum of 10,000 K. This was achieved by cleaning the forehead with an abrasive cleaner and using electrode jelly. Such an arrangement measures not only the activity of the frontalis but also that of the entire facial musculature (15). Budzuski and Stoyva (22) in a biofeedback study reported that relaxation follows when patients can reach and maintain a level of EMG activity not exceeding 3.0 microvolt peak to peak. The subject was asked to aly on a couch in semi-reclining position. The laboratory was dimly lit and its doors were closed while testing to avoid any disturbances from outside. Electronic noise was controlled using the noise suppressor.

The EMG's data were recorded on Honeywell Electronic Medical Systems with Fogg Model 250 EMG Integrator. It expressed the subjects microvolt minimum average over the last 60 seconds. These 60 second readouts were averaged over the three trials of each session.

BLOOD PRESSURE

During this test, blood pressure was measured with an aneroid sphygmomanometer with the subject's arm supported at heart level and a stethoscope applied to the antecubital space over the brachial artery. The cuff was applied with the lower margin about 2.5 cm. above the antecubital space, and the bag was deflated at the rate of 2 to 3 mm. of Hg. per second.

RESPIRATORY MEASUREMENT

CHEST EXPANSION

During this test the chest circumference of the subject was measured as described by Clarke(25). The chest girth was measured in line with the nipples with a non-stretchable tape, with the subject standing and after a full expiration. The second measurement was taken immediately after a full inspiration. Precaution was taken so that the subject did not enlarge the muscles of the chest or back during the measurement. The measurements were repeated and the averages of the two were taken.

VITAL CAPACITY

During this test, the vital capacity of the subject was measured with a Collins Standard Vitalometer, according to the procedure described by Clarke(25). As recommended by him, the subject was directed to take one or two deep breaths before the test. After the fullest possible inhalation, the subject was required to exhale slowly and steadily into the vitalometer, until all the air was expelled.

ASSIGNMENT OF TREATMENTS TO SUBJECTS

The 27 subjects were divided into two categories based on their Predicted VO_2 max on the pre-training rest. One category was below average and the other was above average. They were then, randomly assigned to one of the two groups, Yoga Group (G-1)or control Group (G-2).

TREATMENT

The experimental group(G-1) was subjected to an eight week Yoga training program, consisting of *Asanas* and breathing exercises. The control Group(G-2) was required to maintain their normal daily schedule for eight weeks.

DETAILS OF YOGA TREATMENT

The Yoga training sessions were held in a quiet room in the Department of Physical Education (forty minutes a day, three days a week - Mondays, Wednesdays and Fridays, for eight weeks). Each training session consisted of the nine *Asanas* as indicated further.

Sarvangasana (Shoulderstand pose), *Halasana* (Plough pose), *Matsyasana* (Fish pose), *Pashichimottanasana* (Head to Knee pose), *Bhujangasana* (Cobra pose), *Shalabhasana* (Locust pose), *Dhanurasana* (Bow pose), *Ardha-Matsyendrasana* (Half-spinal Twist) and *Savasana* (Corpse pose) along with *Pranayama* were practiced regularly. The order and the time for which the *Asanas* and *Pranayama* were performed are given in the Table - I.

TABLE - I

Asanas

S. No.	*Asana*	Time
1	*Sarvangasana* (Shoulderstand pose)	1-3 Min.
2	*Halasana* (Plough pose)	2-3 Sec.
3	*Matsyasana* (Fish pose)	30-90 Sec.
4	*Pashichimottanasana* (Head to Knee pose)	30-90 Sec.
5	*Bhujangasana* (Cobra pose)	30-90 Sec.
6	*Shalabhasana* (Locust pose)	30-90 Sec.
7	*Dhanurasana* (Bow pose)	30-90 Sec.
8	*Ardha-Matsyendrasana* (Half-spinal Twist)	30-90 Sec.
9	*Savasana* (Corpse pose)	10 Min

All the postures were practiced in the same order as given above except for *Savasana* which followed the breathing exercises. The order of *Asanas* was chosen according to the direction of movement. The subject was required to concentrate on the *Asana* he was performing.

Sarvangasana, Halasana, Matsyasana, Paschimottanasana, Bhujangasana, Shalabhasana, Dhanurasana, and *Ardh-Masyendrasana* were practiced as described by Lilac (53). *Savasana* was practiced according to Chidananda (24).

FIG. 1 - BHUJANGASANA

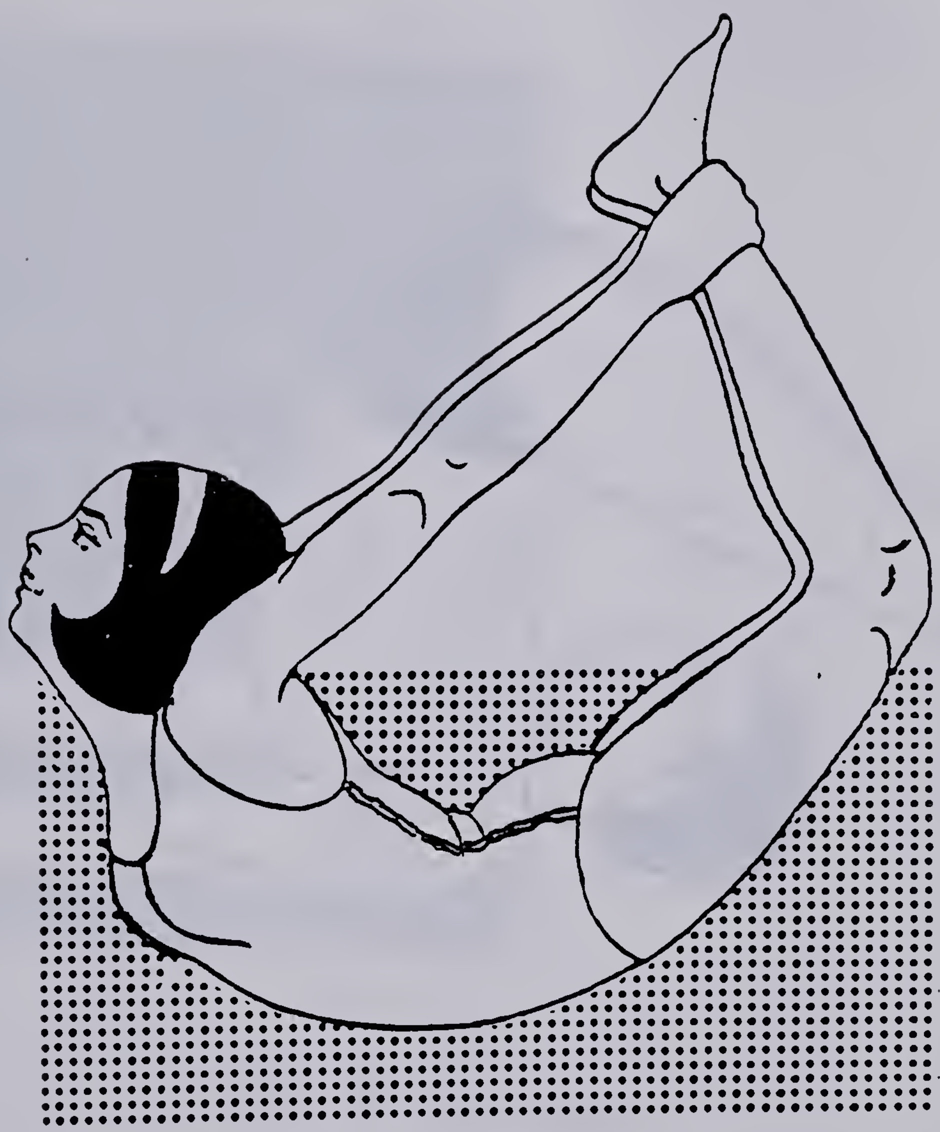


FIG. 2 - DHANUR ASANA

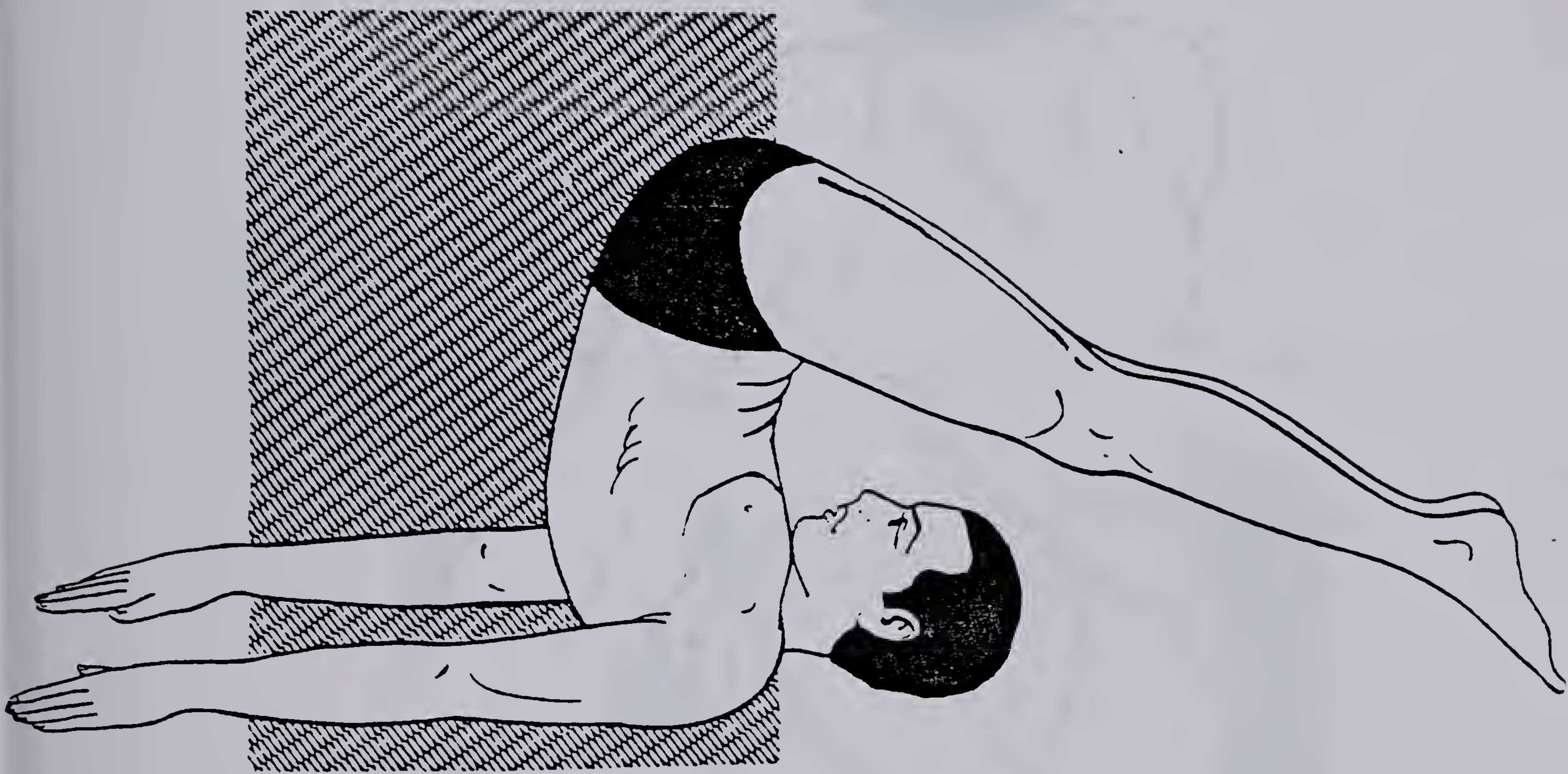


FIG. 3 - HALASANA

FIG. 4 - MATSENDARASANA

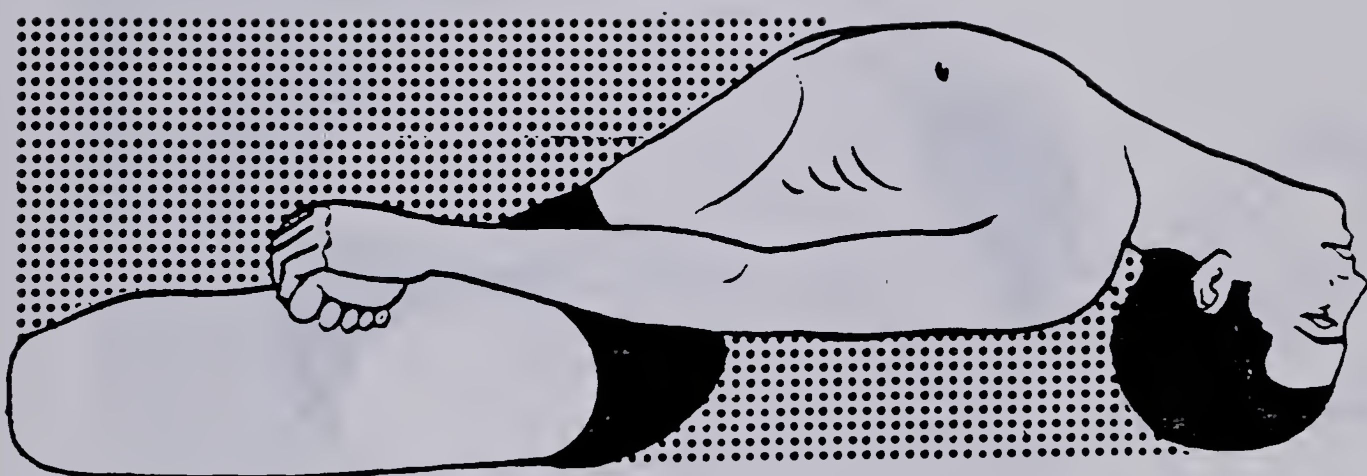


FIG.5 - MATSYASANA

FIG. 6 - PASCHIMOTASANA

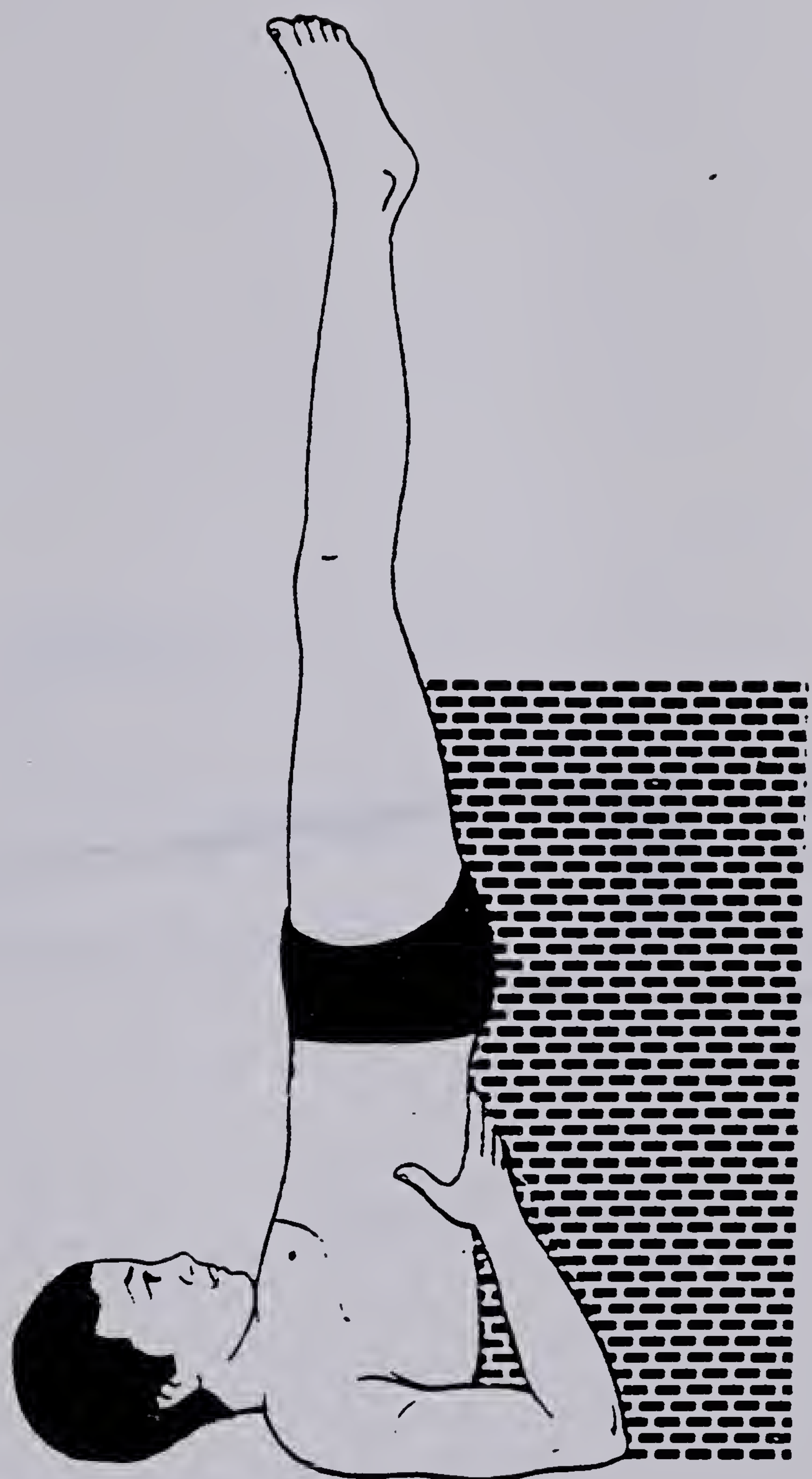


FIG. 7 - SARVANGASANA

FIG. 8 - SAVASANA

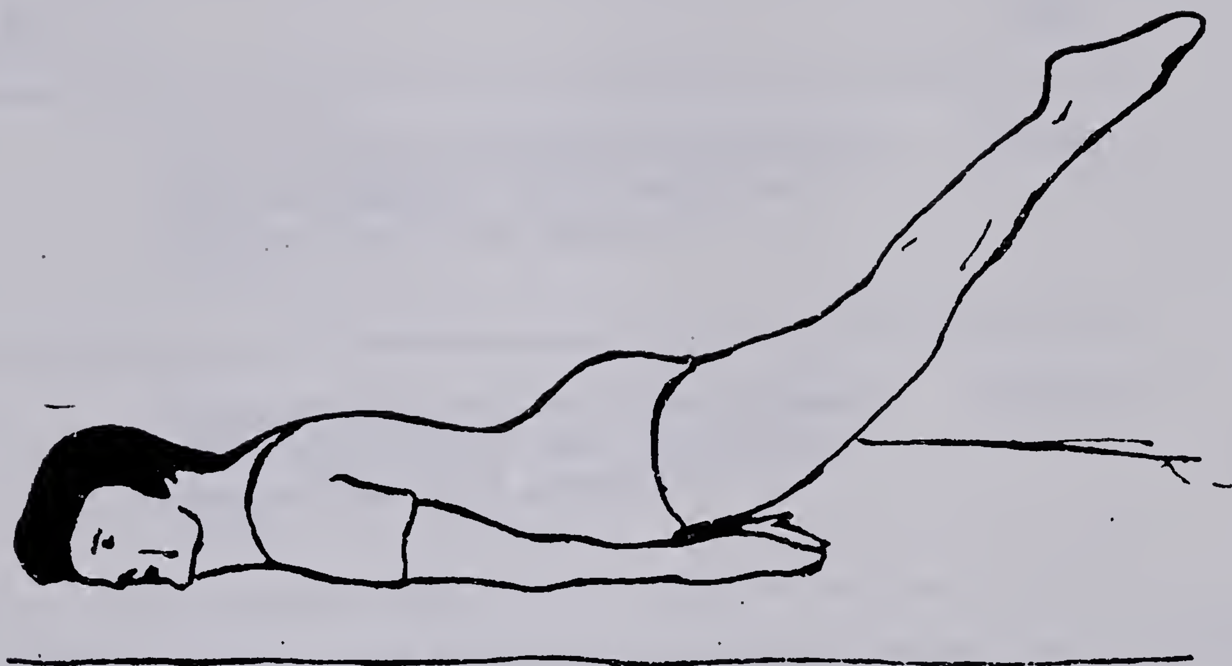


FIG. 9- SHALABHASANA

Pranayama

Pranayama or breathing exercises were practiced as described by Rama et al. (69). The following procedure was followed:

Serial No.		Time
1	Three cycles of exhalation through the left nostril and inhalation through the right nostril	90 Sec.
2	Three cycles of exhalation through the right nostril and inhalation through the left nostril	90 Sec.

This breathing exercise is called *Nadi Shodhanam* (channel purification). During this exercise the exhalation and inhalation were of equal duration (15 sec. each), without a pause between them.

STATISTICAL ANALYSIS

The major purpose of the study was to determine the differential effect of the Yoga treatment. The statistical analysis of the dependent variable was done by two-way analysis of variance with repeated measure on one factor. Further Scheffe method of multiple comparision was applied.

DATA ANALYSIS

The data collected were subjected to a two-way analysis of variance with repeated measure on one factor for each of the following dependent variable:

1 Weight

2 Resting HR

3 Degree of relaxation (Frontalis EMG)

4 Blood pressure

5 Chest expansion

6 Vital capacity

7 Exercise HR

  a 4th min HR

  b 8th min HR

  c 12th min HR

8 Predicted VO_2 Max

Statistical computations were made using the Department of Educational Research Anov. 26. Age and height were subjected to one-way analysis of variance on repeated measure on one factor and were computed using the Department of Educational Research Anov. 14.

Further the Scheffe method of multiple comparison was applied to compare the mean values of different groups during different tests. The statistical level of significance was predetermined at $P < 0.05$.

CHAPTER IV

RESULTS AND DISCUSSION

RESULTS

The following results were obtained from the study done during the course of this research. A total of 27 female volunteers participated in this study. The subjects were divided into two groups; G-1 (Yoga) group had 13 subjects and G-2 (control) group consisted of 14 subjects. (All the data reported in this section are in terms of mean and standard deviation values.)

CHARACTERISTICS OF THE SUBJECTS

Some characteristics of the subjects studied are presented in Table II.

TABLE II

CHARACTERISTICS OF THE SUBJECTS

GROUP	TEST	AGE (YEARS)	HEIGHT (Cm)	WEIGHT (Kg)
G-1	T_1	23.7 ± 3.8	164 ± 7.0	60.6 ± 6.6
	T_2	23.7 ± 3.8	164 + 7.0	60.9 ± 6.5
	T_3	23.7 ± 3.8	164 ± 7.0	61.1 ± 6.6
G-2	T_1	24.0 ± 4.4	164 ± 4.4	59.1 ± 4.3
	T_2	24.0 ± 4.4	164 ± 4.4	59.0 ± 4.2
	T_3	24.0 ± 4.4	164 ± 4.4	58.9 ± 4.4

The average age of the subjects was 23.9 years. The G-1 individuals had average age of 23.7 years whereas the G-2 individuals had 24.0 years of average age. There was not any significant difference in the average age of two groups. The mean height of G-1 group was 164 cms. while that of group G-2 was 164 cms. The statistical test showed that the height is equal for both the groups. The average weight of each group changed during re-training, mid-training and post-training tests. Also the average weights of the two groups differed from one another during all the three tests. All these differences in the average weights were found to be non significant.

Hence, the two groups G-1 and G-2 were fairly homogeneous for the three characteristics studied namely age, height, and weight. No significant change in weight took place as a result of eight weeks of Yoga training.

MEASURES RELATED TO RELAXATION

FRONTALIS EMG

The average EMG activity of the individuals of the G-1 group decreased from 5-7 uv/min. to 3.9 uv/min. during the first four weeks of training. It further decreased to 1.0 uv/min. after training of four more weeks. A summary of mean values of Frontalis EMG activity is shown in Table III.

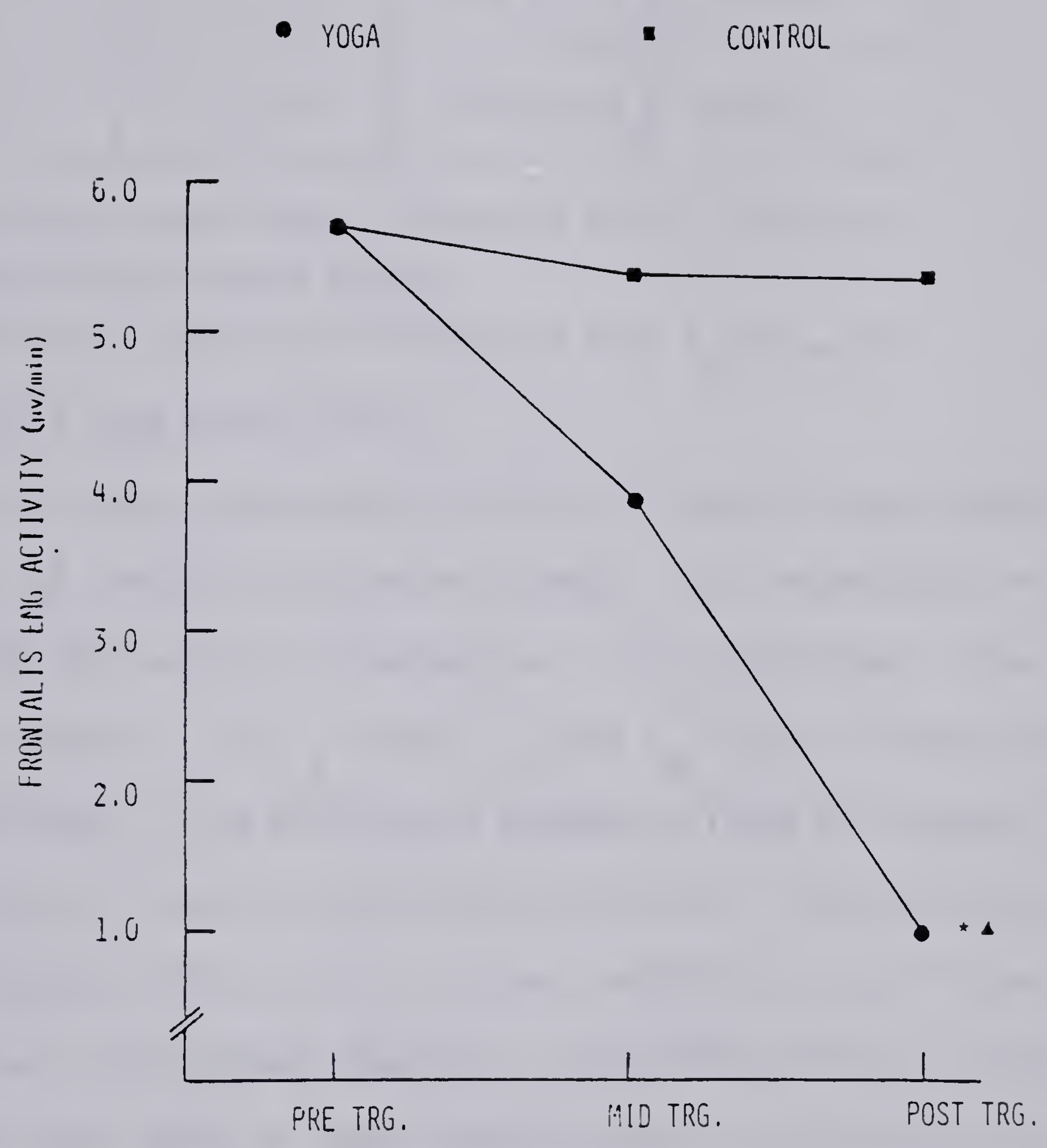


FIG. 10 - EFFECT OF EIGHT WEEKS' YOGA TRAINING ON FRONTALIS EMG ACTIVITY

*indicates significant difference (at $P < 0.05$) from T_1 value of G-1 group.

▲indicates significant difference (at $P < 0.05$) from T_2 value of G-1 group.

TABLE III

FRONTALIS EMG ACTIVITY (μv/min)

GROUP	T_1	T_2	T_3
G-1	5.7 ± 1.9	3.9 ± 1.4	$1.0 \pm 0.3^{*\bullet}$
G-2	5.7 ± 1.3	5.4 ± 1.6	5.4 ± 1.7

* indicates significant difference from T_1 value of Group G-1 (at $p < 0.05$ level)

• indicates significant difference from T_2 value of Group G-1 (at $p < 0.05$ level)

The statistical tests showed a significant difference in the frontalis EMG activity of the Yoga and control groups. The interaction in the treatment and the period of treatment was also significant. The difference between T_1 and T_3 values; T_2 and T_3 values of Yoga group were significant. The differences between G-1 and G-2 values of post training test (T_3) showed significant difference. The control group values of frontalis EMG activity did not indicate any significant change. Thus there was a significant decrease in the EMG activity of frontalis muscle after eight weeks of Yoga training, most of it taking place during the last four weeks of training.

BLOOD PRESSURE

Significant differences for the systolic and diastolic blood pressures were found in the Yoga and control groups. The tests showed a significant decrease in diastolic and systolic blood pressures of G-1 subjects after training. The average diastolic blood pressure

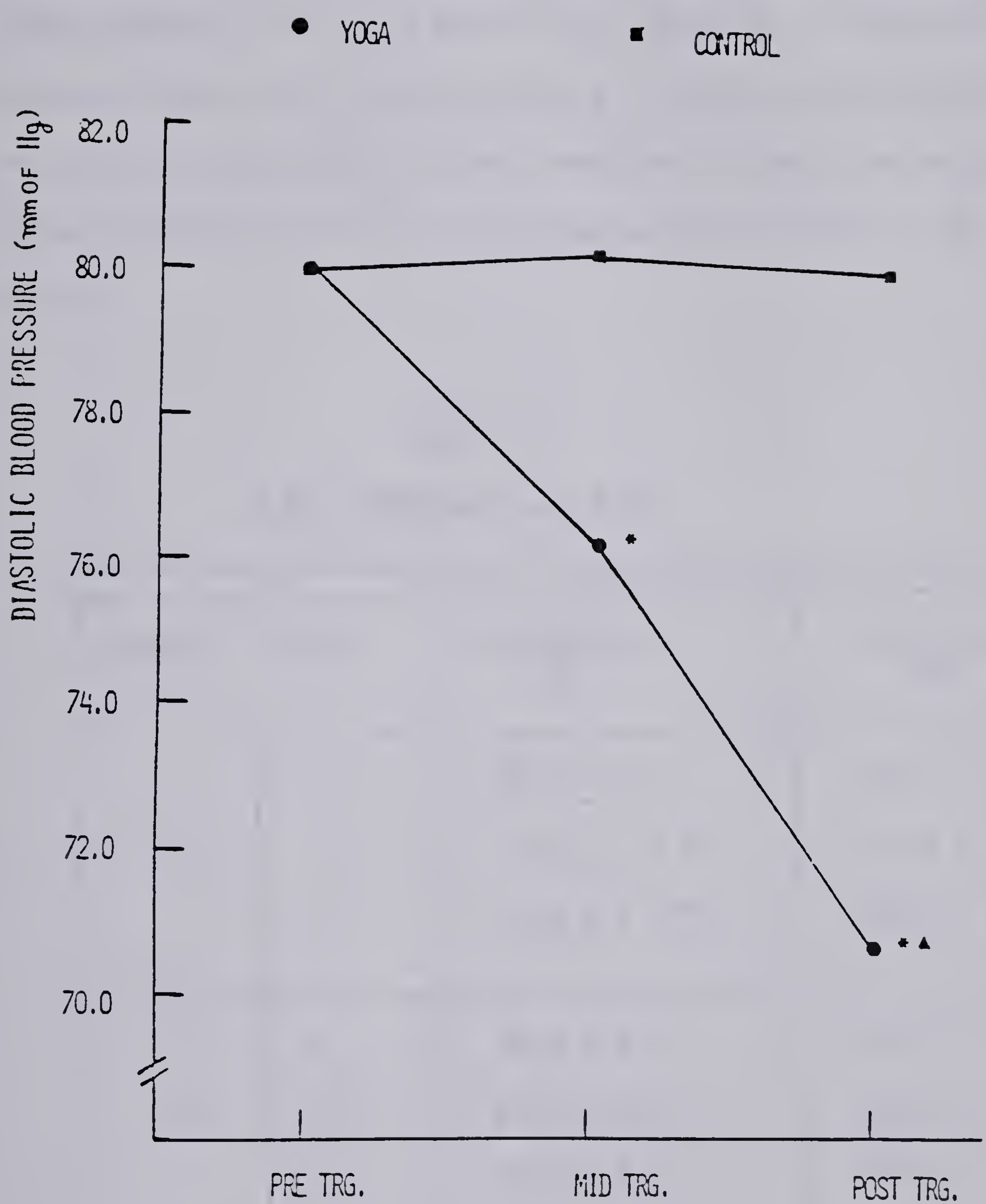


FIG. 11 - EFFECT OF EIGHT WEEKS' YOGA TRAINING ON DIASTOLIC BLOOD PRESSURE

*indicates significant difference (at $P < 0.05$) from T_1 value of G-1 group.

▲indicates significant difference (at $P < 0.05$) from T_2 value of G-1 group.

of the individuals in Yoga group decreased from 80 mm of Hg to 76.1 mm of Hg after first four weeks of training. Pre-training and mid-training tests showed a decrease in the average systolic blood pressure from 119.9 mm to 115.3 mm of Hg. Further this pressure lowered to 108.9 mm of Hg at the end of the training. The diastolic and systlic blood pressures of both the groups during different tests are indicated as mean values in the following Table IV.

TABLE IV

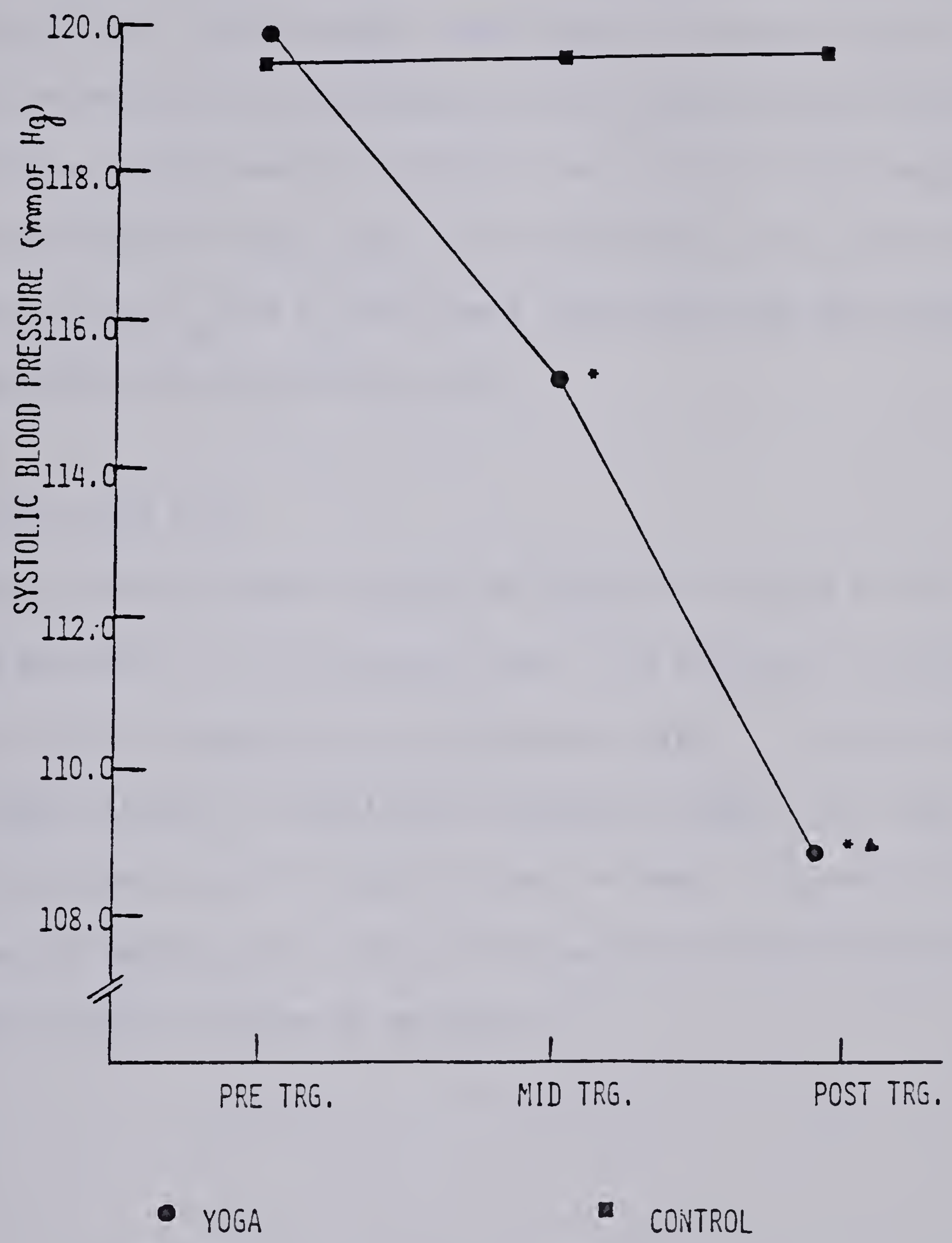
BLOOD PRESSURE (mm of Hg)

GROUP	TEST	DIASTOLIC BP	SYSTOLIC BP
G-1	T_1	80.0 ± 1.5	119.9 ± 1.9
	T_2	76.1 ± 1.5 *	115.3 ± 1.2*
	T_3	70.6 ± 1.3 *•	108.9 ± 1.4*•
G-2	T_1	79.9 ± 2.3	119.5 ± 1.3
	T_2	80.2 ± 2.3	119.7 ± 1.4
	T_3	80.0 ± 2.0	119.8 ± 1.3

* indicates significant difference (at $p<0.05$ level) from T_1 value of Group G-1

• indicates significant difference (at $p<0.05$ level) from T_2 value of Group G-1

FIG.12- EFFECT OF EIGHT WEEKS OF YOGA TRAINING ON SYSTOLIC BLOOD PRESSURE



*indicates significant difference (at $P< 0.05$) from T_1 value of G-1 group.

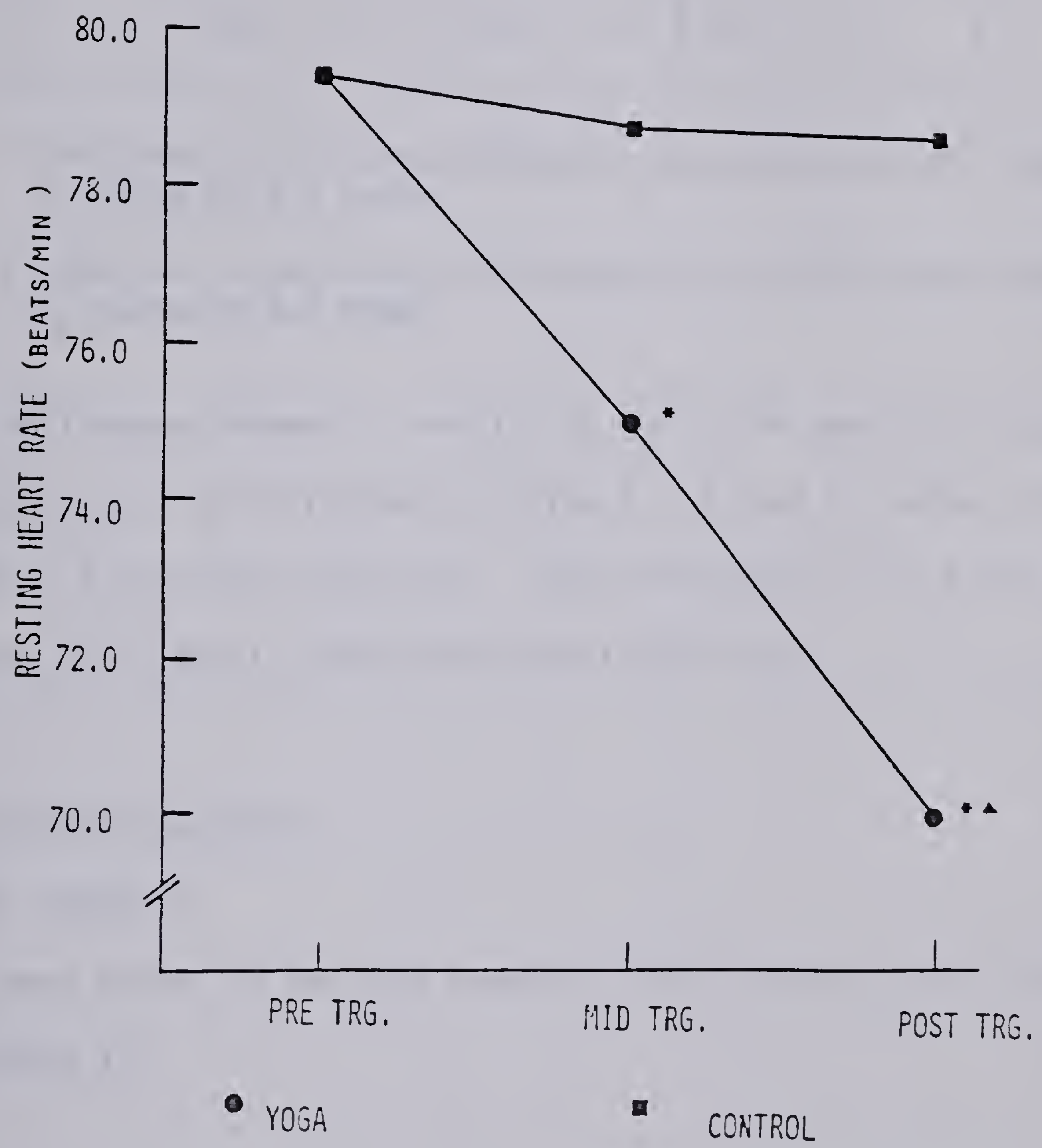
▲indicates significant difference (at $P< 0.05$) from T_2 value of G-1 group.

The total decrease in average diastolic blood pressure was from 80.0 mm of the Hg to 70.6 mm of the Hg and average systolic blood pressure decreased from 119.9 mm of Hg to 108.9 mm of Hg in G-1 group. All the above-mentioned differences in the blood pressures were statistically significant. Pre-training, mid-training and post-training tests did not show any significant variation in the means of diastolic and systolic blood pressures of the subjects of G-2 group. The differences in G-1 and G-2 groups during T_2 and T_3 tests were significant for both diastolic and systolic blood pressure values.

RESTING HEART RATE

The mean resting heart rate of the subjects of group G-1 was 79.4 beats/min. in pre-training test, 75.0 beats/min in mid-training tests and 70.0 beats/min in post training test. So after eight weeks of Yoga training, a significant decrease in heart rate from 79.4 beats/min to 70.0 beats/min was recorded. A summary of mean values of resting heart rate of the subjects of both the Yoga and Control group is given in the Table V.

FIG. 13 - EFFECT OF EIGHT WEEKS' OF YOGA TRAINING ON RESTING HEART RATE



*indicates significant difference (at $P < 0.05$) from T_1 value of G-1 group.
▲indicates significant difference (at $P < 0.05$) from T_2 value of G-1 group.

TABLE V

RESTING HEART RATE (beats/min)

GROUP	T_1	T_2	T_3
G-1	79.4 ± 1.3	75.0 ± 1.1*	70.0 ± 1.1*•
G-2	79.0 ± 1.2	78.8 ± 1.4	78.7 ± 1.3

*indicates significant difference (at $p<0.05$ level) from T_1 value of G-1 group

• indicates significant difference (at $p<0.05$ level) from T_2 value of G-1 group

The difference between T_1 and T_2; T_2 and T_3 of group G-1 were significant. The differences in the T_1, T_2 and T_3 values of group G-2 were non-significant. The differences in G-1 and G-2 groups of T_2 and T_3 tests were also significant.

RESPIRATORY MEASURES

VITAL CAPACITY

The mean values of the test scores on vital capacity are given in Table VI.

TABLE VI

VITAL CAPACITY (l)

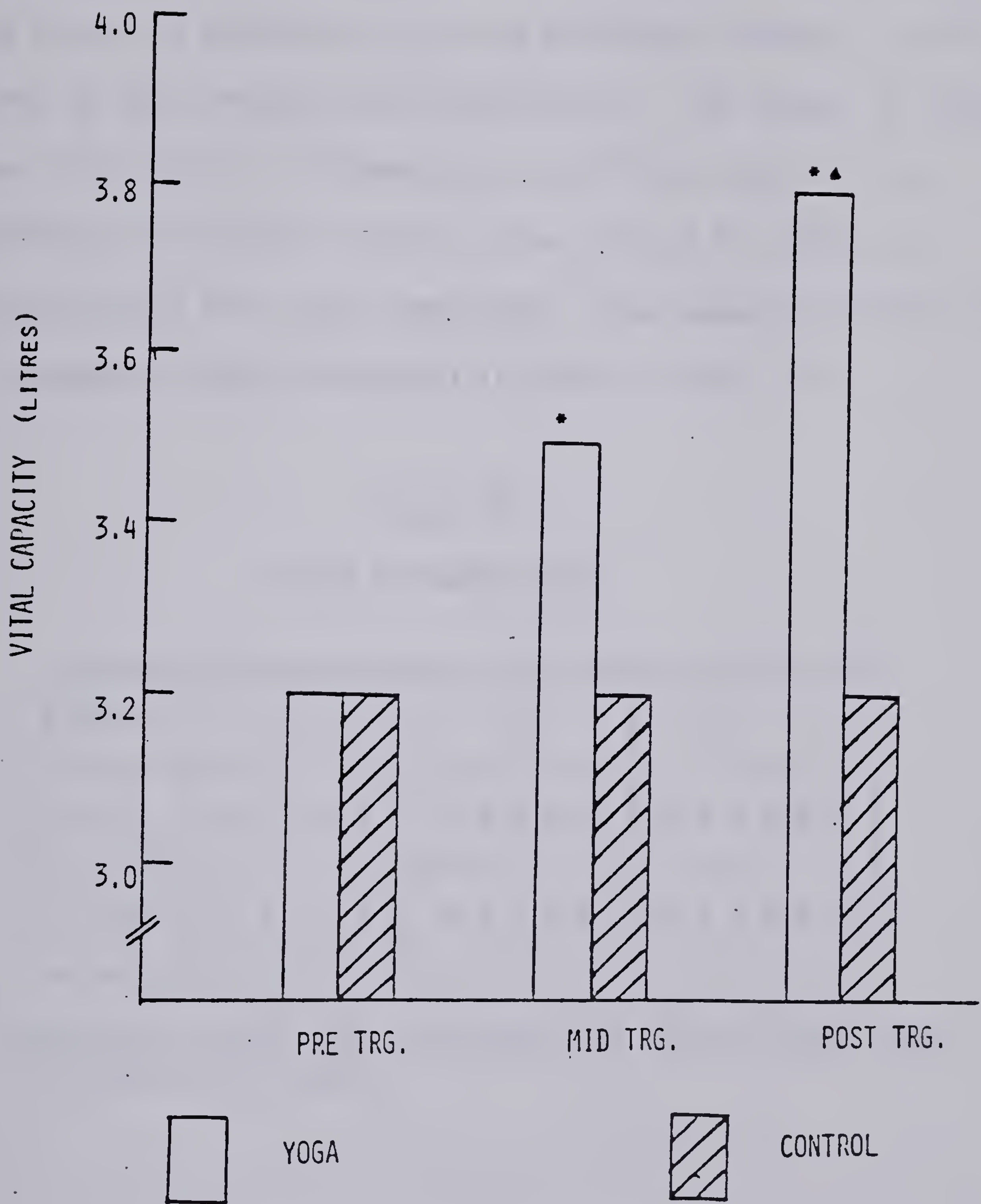
GROUP	T_1	T_2	T_3
G-1	3.2 ± 0.1	3.5 ± 0.1*	3.8 ± 0.1*
G-2	3.2 ± 0.1	3.2 ± 0.1	3.2 ± 0.1

*indicates significant difference (at $p < 0.05$ level) from T_1 value of G-1 group.

*indicates significant difference (at $p < 0.05$ level) from T_2 value of G-1 group.

The mean vital capacity for G-1 group increased from 3.2 l to 3.5 l in the first four weeks of training. It further increased to 3.8 l at the completion of the training. These increases in vital capacity were significant. The differences between Yoga and control groups during Mid and Post training tests were also significant. The vital capacity value of the control group did not change.

FIG.14- EFFECT OF EIGHT WEEKS OF YOGA TRAINING ON THE VITAL CAPACITY



*indicates significant difference (at $P < 0.05$) from T_1 value of G-1 group.
▲indicates significant difference (at $P < 0.05$) from T_2 value of G-1 group.

CHEST EXPANSION

The pre-training chest expansion value of G-1 group was 5.1 cm and it increased to 6.9 cm after training. This difference was statistically significant. The difference between T_1 and T_2 of Yoga group was significant but the difference between T_2 and T_3 values of this group was non-significant. The values for control group (G-2) did not indicate any significant change. The difference in Yoga and control groups during Mid and Post training tests were also significant. The summary of mean values of increase in chest expansion is given in Table VII.

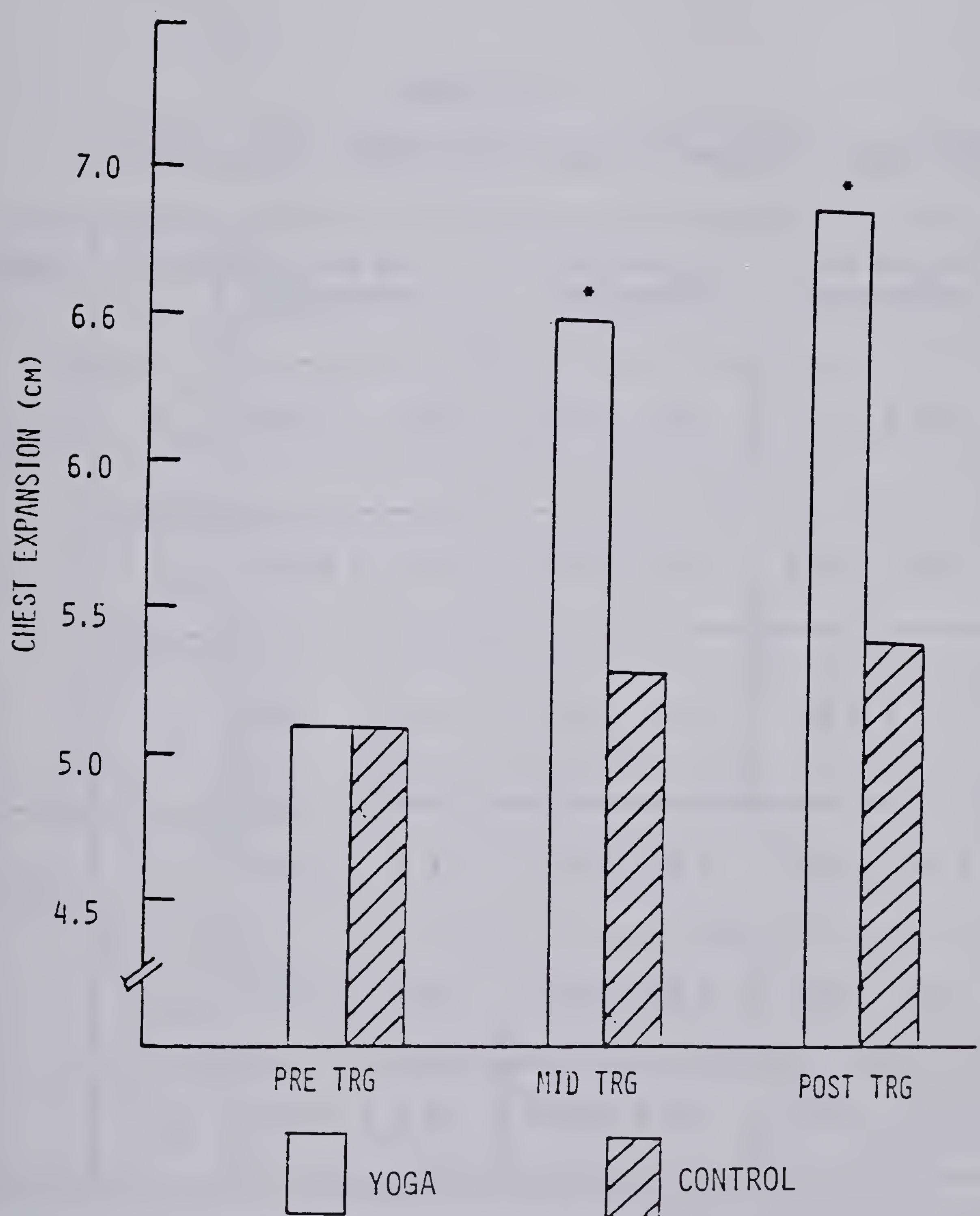
TABLE VII

CHEST EXPANSION (Cm)

GROUP	T_1	T_2	T_3
G-1	5.1 ± 0.2	6.6 ± 0.3*	6.9 ± 0.2*
G-2	5.1 ± 0.5	5.3 ± 0.5	5.4 ± 0.4

*indicates significant difference (at $p < 0.05$ level) from T_1 value of G-1 group

FIG.15- EFFECT OF EIGHT WEEKS OF YOGA TRAINING ON CHEST EXPANSION



*indicates significant difference (at $P < 0.05$) from T_1 value of G-1 group.

EXERCISE HEART RATE AND PREDICTED OXYGEN CONSUMPTION

The mean values of of exercise HRs at the 4th, 8th and 12th min. along with the predicted maximal O_2 consumption are given in Table VIII.

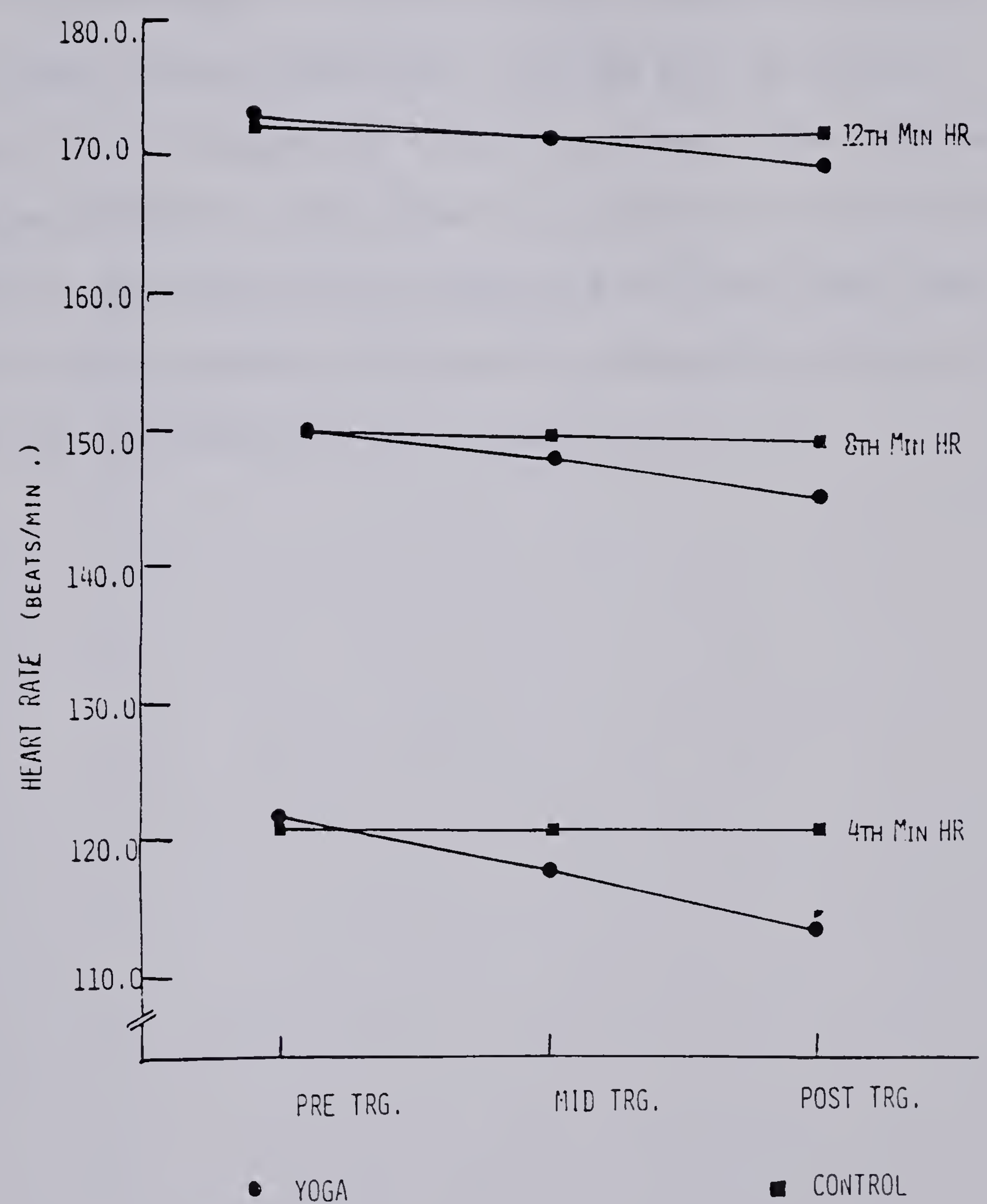
TABLE VIII

EXERCISE HEART RATES AND PREDICTED MAXIMAL OXYGEN CONSUMPTION

GROUP	TEST	12th min HR (beat/Min)	8th min HR (beat/Min)	4th min HR (beat/Min)	Predicted VO_2 (ml/Kg/min)
G-1	T_1	172.8 $\pm$ 3.9	149.9 $\pm$ 3.5	121.7 $\pm$ 3.8	37.0 + 6.8
	T_2	171.6 $\pm$ 3.9	148.2 $\pm$ 3.5	118.1 $\pm$ 3.7	37.8 $\pm$ 6.7
	T_3	169.8 $\pm$ 3.6	145.5 $\pm$ 3.2	113.8 $\pm$ 2.9*	39.3 $\pm$ 6.7
G-2	T_1	172.2 $\pm$ 3.4	149.9 $\pm$ 2.8	122.1 $\pm$ 3.4	36.7 $\pm$ 6.5
	T_2	171.9 $\pm$ 3.3	149.7 $\pm$ 3.0	121.1 $\pm$ 3.1	36.7 $\pm$ 6.3
	T_3	172.1 $\pm$ 3.4	149.8 $\pm$ 3.1	121.0 $\pm$ 3.2	36.7 $\pm$ 6.5

* indicates significant difference (at $p < 0.05$ level) from T_1 values of G-1 group.

FIG. 16- EFFECT OF EIGHT WEEKS OF YOGA ON EXERCISE HEART RATES



*indicates significant difference (at $P < 0.05$) from T_1 value of G-1 group.

A significant change in 4th min. HR of G-1 group with Yoga training was observed as reflected by decrease in heart rate values. The difference between T_1 and T_3 values of G-1 group was significant. While the differences between T_1 and T_2; T_2 and T_3 were non significant. The difference in Yoga and control groups during post Training tests was non significant. The 4th min. HR values of G-2 group did not indicate any significant change. The differences in HR values of 8th min. HR of the G-1 group were non significant. The change in the values of G-2 group were also non significant. The 12th min. HR and predicted maximal O_2 consumption values did not show any significant change in either G-1 or G-2.

TABLE IX

Summary of Physiological Parameters in Yoga and Control Groups - Means, Standard Deviations

Group	Treatment		Age (Yrs)	Height (Cm)	Weight (Kg)	EMG Uv/min	RHR Beat/min	BP(Dis) mm of Hg	BP(Sys) mm of Hg	Chest Exp.(cm)	VC l	HR 4th min	HR 8th min	HR 12th min	P.VO_2 (ml/kg min)
G-1	T_1	$\bar{X}$	23.7	164.0	60.6	5.7	79.4	80.0	119.9	5.1	3.2	121.7	149.9	172.8	37.0
		S.D.	3.8	7.0	6.6	1.9	1.3	1.5	1.9	0.2	0.1	3.8	3.5	3.9	6.8
	T_2	$\bar{X}$	23.7	164.0	60.9	3.9	75.0	76.1*	115.3*	6.5*	3.5*	118.1	148.2	171.6	37.8
		S.D.	3.8	7.0	6.5	1.4	1.1	1.5	1.2	0.3	0.1	3.7	3.5	3.9	6.7
	T_3	$\bar{X}$	23.7	164.0	61.1	1.0*+	70.0	70.6*	108.9*	6.9*	3.8*	113.8*	145.5	169.8	39.3
		S.D	3.8	7.0	6.6	0.3	1.1	1.5	1.4	0.2	0.1	2.9	3.2	3.6	6.7
G-2	T_1	$\bar{X}$	24.0	164.0	59.1	5.7	79.0	79.9	119.5	5.1	3.2	112.1	149.9	172.2	36.7
		S.D.	4.4	4.4	4.3	1.3	1.2	2.3	1.3	0.5	0.1	3.4	2.8	3.4	6.5
	T_2	$\bar{X}$	24.0	164.0	59.0	5.4	78.8	80.2	119.7	5.3	3.2	121.1	149.7	171.9	36.7
		S.D.	4.4	4.4	4.2	1.6	1.4	2.3	1.4	0.5	0.1	3.1	3.0	3.3	6.3
	T_3	$\bar{X}$	20.0	164.0	58.9	5.4	78.7	80.1	119.8	5.4	3.2	121.0	149.8	172.1	36.7
		S.D.	4.4	4.4	4.4	1.7	1.3	2.0	1.3	0.4	0.1	3.2	3.1	3.4	6.5

*indicates significant difference (at $p < 0.05$ level) from T_1 value of G-1 group.

indicates significant difference (at $p < 0.05$ level) from T_2 value of G-1 group.

DISCUSSION

CHARACTERISTICS OF THE SUBJECTS

A nonsignificant difference in the mean age, height and weight between the Yoga and control groups indicated a similar distribution of these characteristics in both the groups. As both groups had a fairly homogeneous distribution of age, height and weight any difference in these groups towards the end of the study were independent of these factors.

MEASURES RELATED TO RELAXATION

FRONTALIS EMG

Research (15,22) has shown that the frontalis muscle is a reliable indicator of the striated muscle activity in the body. The EMG measurement of frontalis muscle does not only generalize to striate muscles of upper body but also serve as a useful indicator of general activity of the sympathetic nervous system. Therefore by monitoring frontalis activity one should be able to obtain a representation of the level of stress in various other striated muscle groups of the body.

Davis et al. (31) argued that the activity of nearby muscles appear in frontalis EMG recordings. The combined activity of the nearby muscles seems desirable in measuring the general relaxation in the present study. The subjects were asked to keep their eyes closed and remain motionless during EMG recordings so that jaw movement,

swallowing and eye movement could not interfere with the measurements. Thus, the EMG measurements of the frontalis muscle activity in this study was considered as a dependable indicator of general muscle tension.

Decreased frontalis muscle activity indicates decreased striate muscle stress and increased relaxation. The subjects of Yoga group were more relaxed after practice of Yoga as indicated by significant decrease in the EMG activity. These results are contradictory to findings of Bagga and Gandhi (12), who did not find any significant difference in EMG activity as a result of regular Yoga practice. The authors have not mentioned the muscle group they used for the study and, hence, a healthy comparison cannot be made.

RESTING HEART RATE

A decrease in the HR of the subjects of Yoga group was expected as other physical exercises also result in a slower HR in the beginners. Low HR in normal people indicates general relaxation. In the present study, it was observed that after training for eight weeks the Yoga group had lower resting HR than prior to the study and as compared to that of the control group. This is in agreement with the studies of Udupa (83), Dhanaraj (33), and Bagga et al. (12).

There are observations that slowing of HR after a period of physical training with a standard work load, is induced by an increase in vagus tone and a reduction in sympathetic drive (9). Tipton (80) confirmed that lowering of HR is brought about by an increased vagal impulse. As a decrease in HR of young women has been observed, it appears that Yoga training reduces or counteracts the increased sympathetic nervous system activity responsible for increased HR. Further it would infer that this type of training stimulates vagal nerve thus producing more acetylcholine which results in lower HR. It might, therefore, be summarised that Yoga training results in lowering the HR by (i) a parasympathetic inhibition, or (ii) a decreased sympathetic influence, or (iii) a combination of both.

If the above assumption is true then it would appear that Yoga training should be useful in alleviating the diseases where increased sympathetic nervous system activity is a principal factor in the development of the disease. However, research is currently being carried out to test the usefulness of Yoga relaxation in treating the cardiac problems. Tulpule and Tulpule (82) observed that *Yogasana* and *Pranayama* training reduced mortality rate in the patients of myocardial infraction. They concluded that lack of relaxation is an important risk factor and relaxation could be induced by maintaining low HR and blood pressure with the Yoga training.

In normal individuals low HR is known to be a positive sign of cardiovascular efficiency. It is generally believed that a slower HR accompanies a relatively larger stroke volume, so as to maintain a certain level of cardiac output. This, from the energy expenditure point of view, may be interpreted as an economical adaptation, requiring less oxygen than a faster beating heart at the same cardiac output level.

BLOOD PRESSURE

Statistically significant decreases in systolic as well as diastolic BP were observed in the subjects of Yoga group. The results of the present study are in confirmation with the studies done by Udupa et al. (85,87.) In those studies the subjects were trained in basic *Asanas* excluding *Savasana*. However, Bagga et al. (12) observed a more pronounced drop in BP with *Savasana*.

Savasana has been used to reduce the mortality rate due to hypertension. Datey et al. (28) reported that the hypertensive patients undergoing *Savasana* training could decrease their BP. In similar studies, Patel (64) also observed reduction in the BP of hypertensive patients with *Savasana* and biofeedback training. Datey et al. (28) suggested that this exercise probably influences the hypothalamus through continuous feedback training. It would appear that the practice of basic *Asanas* and *Pranayama* influence the circulatory system via nervous systems and tones down its activity, thus,

producing generalized relaxation. Diagamberji et al. (35) also reported that the regular practice of *Asanas* improve ones capacity to relax physically and mentally.

The Yoga subjects reported very relaxed after each training session. According to their opinion in the post-training questionnaire they were very relaxed. It is possible that subjective opinion might accurately reflect a general relaxation. No significant change was observed in the control group. Relaxation being inhibitory response of stress, it is assumed that the tension is reduced in Yoga group with the practice of *Asanas* and *Pranayama*. It is not possible to specify which of the following contribute more to general relaxation. The *Asanas* and *Pranayama; Savasana* and *Pranayama;* or only *Savasana*. The practice of selected *Asana* and *Pranayama* have been reported (7) to increase stability in autonomic responses with beneficial effects on mental and physical health along with greater relaxation and reduction in tension. During the training, following three factors appeared to have contributed to relaxation: (i) to focus ones awareness on physical posture; (ii) to practice diaphragmatic breathing in *Pranayama*; (iii) to relax the neuromuscular tension with the practice of *Savasana*.

The practice of Yoga, according to Everly (36), involves focusing of one's awareness on some physical act which has the potential of inducing the relaxation state. Naranjo and Ornstein (60), called it a focal device or something to 'dwell upon'. Exactly how the

Yoga works, no one knows for sure, however, Naranjo and Orenstein's theory of focal device seems appropriate. According to them, the role of the focal device is to engage the left hemisphere's neural circuitry to allow the right hemisphere to become dominant. Thus, the focal device occupies the left hemisphere by engaging it in a set of postures. When the focus devise is successfully employed, the brain order of processing appears to be altered and thus results in relaxation. Sometimes, the focal device gets overloaded and frustrates the left hemisphere. This could be the case when one engages in rigorous Yoga training without proper guidance. For the purpose of safety, it is advised to do Yoga practice once a day, not holding a posture for more than 5 to 7 minutes and not repeating them.

During the practice of *Pranayama*, the subjects of Yoga group were directed to breath in and out using diaphragm, since it is the deepest of all the breaths. The literature of Yoga offers numerous and diverse respiratory techniques for relaxation. The significance of diaphragmatic breathing is highlighted although the mechanism of relaxation with diaphragmatic breathing is not yet fully understood. Hymes (47) noted that the tone of sympathetic and parasympathetic nervous systems is generally affected by the process of respiration and autonomic functioning may be voluntarily shifted back to calm by conscious breath control. According to Harvey (45) diaphragmatic

breathing stimulates both the solar plexus and the right vagus nerve in a manner that innervates the parasympathetic nervous system, thus facilitating full relaxation. However, Ballentine (13) hypothesized that expiration increases parasympathetic tone. It is interesting to note that in *Pranayama* diaphragmatic breathing during expiration is pratracted and thus, likely results in parasympathetic relaxation. Although, the specific mechanisms involved in stress reduction via breath control may differ from via breath control may differ from technique to technique, diaphragmatic breathing in variably results in inducing a temporary state of relaxation.

Savasana is known to be a definite technique to reduce neuromuscular tension and to achieve greater neuromuscular relaxation through conscious effort. Govindarajulu (43) and Kuvalayananda (52) have described the efficacy of this *Asana* as a scientific way of relieving fatigue. Jacobson's (49) method of progressive relaxation is also based on neuromuscular relaxation. In this type of training, one learns to enhance one's awareness of proprioceptive neuromuscular impulses which originate at the peripheral muscular levels and increase with striate muscle tension, and it may be true in the case of *Savasana* training too. According to Jacobson, these afferent proprioceptive impulses are major determiners of anxiety and overall stressful sympathetic arousal. Although,

it is not clear what mechanisms work in *Savasana*, however, the practice of *Savasana* has been proven scientifically to improve the degree of relaxation in hypertensive patients.(82).

The significance of relaxation in sports has been overlooked and there is a need for research in this area. Knowing, whether, the body is relaxed or tense, is basic to physical conditioning. Prior to learning skills and engaging in exercise, it is perhaps necessary to develop the ability of detecting muscular tension and the means of reducing it through relaxation techniques. Dhanaraj (33) in a recent study observed that Yoga-type relaxation practised after sports offers special benefits to participants. However, further investigations are necessary in physiology and psychology, before any definitive conclusion could be drawn.

RESPIRATORY MEASURES

VITAL CAPACITY

The results of the test on vital capacity points out that as a result of training, the Yoga group has improved significantly. The present study is in agreement with the studies of Dhanaraj (33), Gopal et al. (42) and Nayer et al. (61). Udupa et al. (85) observed the effects of Yoga on vital capacity and other physiological measures. They found a greater increase in VC with the practice of poses like *Sarvangasana* and *Matsyasana* than *Pranayamic*

exercises. Some of the other studies (18) found striking increase in VC with the combination of some Yogic and *Pranayamic* exercises.

Vital Capacity has been a controversial issue in physical education testing, especially since Rodgers (70) included it in his strength test battery. This test was also included in the studies by Tomaras (81); Clarke and Carter (26). In general, it is known to be a measure of body size but it also has a high correlation with body strength. Tomaras obtained a correlation of .86 with the average of seven upper body cable tension strength tests, .84 with McClay's athletic strength index and .80 with Rodgers' strength index. For college men, Davis (30) obtained a correlation of .59 between lung capacity and time for the 200 yards free style swim. Some researches seem to indicate that physical training has no effect on vital capacity. Based on the findings of others, Astrand and Rodahl (9) inferred that VC is likely to increase in the case of young people. As regards Yoga, there is positive evidence that *Asanas* coupled with *Pranayama* would cause an increase in VC (19).

The possible processes and mechanisms responsible for the increase in VC are not clearly understood. *Pranayama* breathing emphasize slow and deep breathing, stress being on more prolonged expiration and efficient use of abdominal muscles, this may help to increase VC. This would further appear to help the efficient movements of the diaphragm and improve lung ventilation. According to Bhole et al. (20), *Asanas* remove tension from the skeletal muscles and this help the

diaphragm to function better. However, the practice of *Asanas* and *Pranayama* seem to increase expiratory reserve volume thereby increasing the vital capacity.

CHEST EXPANSION

The Yoga group significantly improved in chest expansion after training. It was interesting to note that most of the changes occured in first four weeks of the training. The overall improvement shown was probably due to the effects of breathing exercises and the *Asanas* involving chest muscles. The results are in agreement with the studies of Dhanaraj (33) and Udupa et al. (86). However, Udupa et al. observed the significant changes in the chest expansion with some Yoga postures only (without *Pranayama*). Nevertheless, their subjects underwent a training for six months. It should be taken into account that the study was limited to a small sample and the treatment group was not compared to any control. The author did not mention the duration of the training sessions. Dhanaraj (33) studied the effects of Yoga scientifically but confined the study to male subjects only. So, it may not be fair to compare the result of this study to any of the earlier studies.

Many Yoga teachers have claimed that the respiratory system improves with Yoga training. From a physiological point of view, the importance of chest expansion is not clear. Yet it is known to be an indicator of efficient respiration. The deep inspiration brought about by the active contraction of the diaphragm and the

intercostle muscle seem to allow the rib cage to expand and fill the lungs with air. It would appear that expansion of chest allows optimal interchange of gases in the lungs.

During the normal breathing, ventilation of alveoli, where the diffusion process occurs, has been attributed to the enlargement of the alveolar duct. The expansion in chest may facilitate the enlargement of alveolar area and consequently it may improve the whole diffusion process. The movements made by diaphragm and thoracic cage may also improve the oxygen supply of the blood by accelerating the venous circulation. Circulatory efficiency is closely related to respiration. Since, to work efficiently muscles are dependent upon oxygen as insufficient amount of oxygen cause the accumulation of lactic acid in the blood, which impedes the contraction of muscle.

Physical conditioning definitely affects the efficiency of the respiratory system. As a result of training, the expansion of chest is increased and the depth of breathing is augmented (41). Furthermore (19) it has been shown that a person in good physical condition breathes less air and at the same time absorbs greater percentage of the oxygen from the air he breathes than does the average person. However, to determine the implication of chest expansion in exercise physiology further scientific investigation is required.

EXERCISE HEART RATES AND PREDICTED OXYGEN CONSUMPTION

The 8th min. and 12th HRs did not indicate any significant change with Yoga training. The difference in the predicted oxygen consumption before and after eight weeks training session was not significant. Yoga training did not have sufficient impact on O_2 transport system to elicit a training effect on exercise HRs at the 8th and 12th min. or maximal O_2 consumption.

The post training scores indicate that Yoga group (G-1) had improved significantly. The physical training seems to have a wide range of effects on maximal O_2 consumption (5-43% improvement) as given by Masicotte. This improvement cannot be attributed to physical training (55). The indications are that Yoga subjects developed efficiency at a moderately high HR. Though these results are in accordance with the study of Dhanaraj (33); yet further investigations are needed to evaluate this phenomenon.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

SUMMARY

The growing popularity of Yoga among females encouraged the investigator to study the physiological effects of this training on them. Twenty-three female students (mean age 23.8 years) were used as subjects. After the pre-training tests, the subjects were randomly assigned to two groups, namely Yoga (G-1) and control (G.-2). Yoga group was given eight weeks' training in selected *Hatha Yoga* exercises, while, control group did not receive any training. The subjects of control group maintained the same physical training level to which they were used to. Both the groups were tested after four weeks and after eight weeks. The data collected were subjected to stastical tests of significance at < 0.05 level.

The Yoga group improved in measures related to relaxation. The frontalis EMG activity of the subjects practising Yoga decreased significantly (from 5.7 to 1.0 μv/min.) The resting heart rate lowered significantly (from 79.4 to 70.0 beats/min.). Both the systolic and diastolic blood pressures dropped significantly (Systolic BP: from 119.9 to 108.9; Diastolic BP: 80.0 to 70.6 mm of Hg).

The significant increases in Vital Capacity (from 3.2 to 3.8 l) and chest expansion (from 5.1 to 6.9 cm) indicated a considerable improvement in the respiratory measures. The cardiovascular measures

of the Yoga group did not improve much, however, the 4th min exercise HR values decreased significantly from T_1 to T_3. The control group indicated no significant changes in HR response to exercise.

CONCLUSIONS

Within the limitations of this study, the following conclusions appear justified regarding the physiological effects of Yoga training on young females:

1. Yoga training improves the ability to relax.
2. Yoga training increased the vital capacity and chest expansion.
3. Yoga training does not improve predicted Vo_2 max.

The effects of Yoga on females were similar to that of males as indicated by previous studies.

RECOMMENDATIONS

1. Studies to determine the effects of training of Yoga and other fitness programs together.
2. Experiments to determine the effects of selected *Asanas*, *Pranayama* or *Asanas* separately.
3. Research to evaluate the applications of Yoga to sports that require flexibility, breath holding and other factors.
4. Studies to determine the effects of Yoga on people of different age groups and both sexes.

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APPENDIX A

QUESTIONNAIRES

PRE-TRAINING QUESTIONNAIRE

Name ____ Date of Birth __________
(First) (Last)

Home Address ____________________________________ Phone ____________

Did you ever undertake a Yoga Program?

NO YES

If yes, indicate the total period of your participation.

DAYS MONTHS YEARS

How much time do you spend in physical activities (games, sports, physical recreation)?

HOURS/DAY DAYS/WEEK WEEKS/YEAR

Did you participate in any organized physical training during the last six months?

NO YES

If yes, indicate the type of training and total period of participation.

Do you have any medical problems?

NO YES

If yes, please specify ____

Give particulars of past medical history in brief.

____

____

Do you smoke?

NO YES

Other comments if any ____

____

Signature ________________________

Date ________________________

POST-TRAINING QUESTIONNAIRE

Name: ______________________________________

Circle one appropriate number of each question. Use the line below for additional information.

1 = Yes 2 = Partly True 3 = Not Sure 4 = No

During Training

1. Participation experience was satisfactory 1 2 3 4

. . . .

2. The sessions where physically taxing 1 2 3 4

. . . .

3. Maintaining the tempo of training was hard 1 2 3 4

. . . .

4. I understood fully the purpose of experiment 1 2 3 4

. . . .

5. My interest remained unabated 1 2 3 4

. . . .

After Training

6. My general health has improved 1 2 3 4

. . . .

7. I am now able to withstand more strain 1 2 3 4

. . . .

8. I now feel more light and relaxed 1 2 3 4

. . . .

9. Rest is now more refreshing and meaningful 1 2 3 4

. . . .

10. My mental concentration has improved 1 2 3 4

. . . .

Other comments, if any: . . . .

APPENDIX B

RAW SCORES

YOGA - PRE TRAINING

No.	Age (yrs.)	Ht. (cm.)	Wt. (kg.)	RHR (b/min.)	BP(Dis) (mm of Hg.)	BP(Sys) (mm of Hg.)	EMG (µv/min.)	Ch. exp. (cm.)	Vc (1.)
1	21	162.5	58.3	80	82	122	8.1	5.6	3.0
2	27	160.0	51.5	81	78	118	4.8	4.3	3.4
3	27	175.3	67.5	78	79	117	3.6	5.1	3.3
4	18	165.1	67.5	79	82	120	6.3	5.0	3.2
5	21	161.3	63.0	78	81	120	3.8	5.3	3.4
6	28	160.0	61.0	80	80	123	5.1	4.3	3.2
7	26	165.0	57.8	79	80	118	3.8	4.8	3.1
8	27	163.8	48.8	80	79	122	4.7	5.8	3.0
9	26	168.4	56.5	80	78	119	4.9	5.0	3.2
10	24	165.1	65.0	77	78	118	6.3	5.0	3.1
11	19	160.0	56.7	82	80	119	9.1	5.5	3.1
12	18	180.3	74.0	80	82	121	5.1	5.3	3.4
13	27	152.4	60.7	79	82	122	9.2	4.9	3.2

YOGA - PRE TRAINING

No.	4th min. HR (b/min.)	Workload (kpm/min.)	8th min. HR (b/min.)	Workload (kpm/min.)	12th min. HR (b/min.)	Workload (kpm/min.)	PVo_2 max. (ml/kg/min.)
1	130	372	153	732	174	915	34
2	122	558	150	912	175	1272	53
3	118	555	145	934	169	1290	28
4	121	440	155	740	179	910	28
5	123	560	154	920	170	1090	38
6	122	470	151	720	177	1095	36
7	123	540	149	756	168	990	39
8	117	450	150	720	174	900	34
9	124	540	151	810	170	1010	34
10	114	545	143	900	169	1260	45
11	120	470	144	720	168	900	39
12	119	540	150	900	179	1260	35
13	125	270	152	360	174	540	25

YOGA - MID TRAINING

No.	Age (yrs.)	Ht. (cm.)	Wt. (kg.)	RHR (b/min.)	BP(Dis) (mm of Hg.)	BP(Sys) (mm of Hg.)	EMG (µv/min.)	Ch. exp. (cm.)	Vc (l.)
1	21	162.5	58.9	76	79	118	4.9	6.8	3.4
2	27	160.0	51.8	77	74	115	2.7	6.1	3.6
3	27	175.3	67.8	74	75	114	2.2	6.3	3.6
4	18	165.1	67.7	76	78	116	4.3	7.1	3.5
5	21	161.3	63.4	74	76	114	2.1	6.6	3.7
6	28	160.0	61.4	76	76	117	3.8	5.8	3.5
7	26	165.0	58.3	75	77	114	2.0	6.6	3.4
8	27	163.8	49.1	74	75	116	4.2	7.6	3.4
9	26	168.4	56.8	74	75	114	4.0	6.8	3.5
10	24	165.1	65.2	74	74	115	4.2	6.6	3.5
11	19	160.0	57.2	76	77	115	7.2	7.3	3.4
12	18	180.3	74.3	76	77	116	3.9	6.8	3.7
13	27	152.4	60.8	74	77	116	5.5	5.3	3.5

YOGA - MID TRAINING

No.	4th min. HR (b/min.)	Workload (kpm/min.)	8th min. HR (b/min.)	Workload (kpm/min.)	12th min. HR (b/min.)	Workload (kpm/min.)	PVo_2 max. (ml/kg/min.)
1	126	372	151	732	173	915	34
2	118	558	148	912	174	1272	53
3	114	555	144	934	167	1290	43
4	116	440	153	740	178	910	29
5	120	560	152	920	169	1090	40
6	119	470	148	720	175	1095	36
7	119	540	147	756	166	990	39
8	114	450	148	720	172	900	36
9	121	540	150	810	168	1010	36
10	112	545	142	900	168	1260	45
11	116	470	142	720	167	900	39
12	114	540	147	900	178	1260	36
13	122	270	150	360	173	540	25

YOGA - POST TRAINING

No.	Age (yrs.)	Ht. (cm.)	Wt. (kg.)	RHR (b/min.)	BP(Dis) (mm of Hg.)	BP(Sys) (mm of Hg.)	EMG (μv/min.)	Ch. exp. (cm.)	Vc (l.)
1	21	162.5	59.0	71	74	110	0.7	7.3	3.7
2	27	160.0	52.3	73	70	112	1.3	6.6	3.8
3	27	175.3	68.4	70	70	109	0.5	6.8	3.8
4	18	165.1	68.2	70	70	110	1.2	7.4	3.8
5	21	161.3	63.6	69	70	108	1.0	7.1	3.9
6	28	160.0	61.4	71	71	107	1.3	6.3	3.8
7	26	165.0	58.3	69	73	109	0.8	7.1	3.7
8	27	163.8	49.3	69	70	110	1.0	7.6	3.6
9	26	168.4	57.0	69	70	107	1.2	7.1	3.8
10	24	165.1	65.3	69	69	110	0.9	7.3	3.8
11	19	160.0	57.3	70	71	109	0.9	7.1	3.7
12	18	180.3	74.4	71	70	108	1.0	6.9	4.0
13	27	152.4	61.0	70	70	107	1.2	5.6	3.8

YOGA - POST TRAINING

No.	4th min. HR (b.min.)	Workload (kpm.min.)	8th min. HR (b/min.)	Workload (kpm/min.)	12th min. HR (b/min.)	Workload (kpm/min.)	PVo_2 max. (ml/kg/min.)
1	118	372	148	732	171	915	36
2	113	558	145	912	171	1272	55
3	110	440	142	934	166	1290	44
4	111	560	150	740	175	910	31
5	117	570	150	920	168	1090	41
6	114	470	145	720	172	1095	38
7	114	540	144	756	164	990	41
8	110	450	145	720	171	900	38
9	116	540	146	810	165	1010	38
10	110	545	140	900	168	1260	46
11	111	470	140	720	165	900	40
12	111	540	144	900	175	1260	38
13	119	270	148	360	172	540	26

CONTROL - PRE TRAINING

No.	Age (yrs.)	Ht. (cm.)	Wt. (kg.)	RHR (b/min.)	BP(Dis) (mm of Hg.)	BP(Sys) (mm of Hg.)	EMG (µv/min.)	Ch. exp. (cm.)	Vc (l.)
1	19	167.6	66.0	80	78	119	5.3	6.3	3.0
2	24	165.1	57.5	77	77	118	8.0	5.0	3.4
3	23	160.0	60.4	79	80	119	5.6	6.8	3.2
4	27	162.7	61.9	80	79	120	4.7	4.2	3.4
5	26	167.4	56.5	80	85	122	4.9	4.5	3.0
6	18	161.2	57.8	78	80	121	6.0	5.6	3.2
7	29	163.8	57.7	81	82	122	5.2	5.2	3.2
8	28	167.6	55.0	79	83	118	4.7	5.0	3.1
9	28	156.9	67.5	78	77	119	5.8	4.8	3.2
10	28	162.5	57.0	79	80	118	5.7	4.8	3.3
11	20	170.8	50.0	80	77	120	4.7	5.1	3.2
12	20	163.8	63.5	79	82	119	4.2	4.2	3.1
13	29	162.5	60.0	80	80	118	3.3	5.1	3.3
14	17	173.7	56.7	77	79	120	3.2	5.5	5.8

CONTROL - PRE TRAINING

No.	4th min. HR (b/min.)	Workload (kpm/min.)	8th min. HR (b/min.)	Workload (kpm/min.)	12th min. HR (b/min.)	Workload (kpm/min.)	PVo_2 max. (ml/kg/min.)
1	118	540	146	990	167	1260	38
2	122	550	152	910	174	1270	42
3	124	554	153	910	172	1260	36
4	116	550	148	910	169	1270	34
5	120	360	149	540	178	630	26
6	119	550	151	904	170	1090	46
7	130	270	155	360	175	540	26
8	122	450	151	630	171	900	39
9	126	360	150	540	175	910	31
10	122	450	147	720	169	972	39
11	121	545	144	725	168	910	46
12	123	370	152	720	177	910	30
13	120	468	148	725	166	915	45
14	123	540	148	905	164	1085	36

CONTROL - MID TRAINING

No.	Age (yrs.)	Ht. (cm.)	Wt. (kg.)	RHR (b/min.)	BP(dis) (mm of Hg.)	BP(Sys) (mm of Hg.)	EMG (µv/min.)	Ch. exp. (cm.)	Vc (l.)
1	19	167.6	66.0	78	79	118	4.8	6.4	3.1
2	24	165.1	57.4	77	79	118	8.0	5.3	3.4
3	23	160.0	60.4	78	81	120	5.9	6.8	3.2
4	27	162.7	60.3	78	80	118	5.6	6.9	3.2
5	26	167.4	62.0	80	78	120	4.6	4.5	3.4
6	18	161.2	57.1	81	80	121	4.5	4.6	3.1
7	29	163.8	57.7	76	80	121	6.0	5.8	3.2
8	28	167.6	57.6	80	82	123	5.2	5.2	3.2
9	28	156.9	54.8	78	82	120	4.6	5.3	3.1
10	28	162.5	67.3	80	76	120	5.7	5.0	3.2
11	20	170.8	57.1	80	81	120	5.7	5.0	3.2
12	20	163.8	49.7	78	77	118	4.5	5.3	3.2
13	29	162.5	62.8	79	83	118	4.0	5.3	3.1
14	17	173.7	60.1	81	79.0	119	8.5	5.1	3.3

CONTROL - MID TRAINING

No.	4th min. HR (b/min.)	Workload (kpm/min.)	8th min. HR (b/min.)	Workload (kpm/min.)	12th min. HR (b/min.)	Workload (kpm/min.)	PVo_2 max. (ml/kg/min.)
1	117	540	145	900	169	1260	38
2	120	550	151	910	174	1270	42
3	123	554	154	910	172	1260	36
4	122	554	153	910	173	1260	36
5	116	550	148	910	169	1270	34
6	119	360	149	540	178	630	26
7	118	550	150	905	169	1270	34
8	128	270	155	360	175	540	26
9	121	450	150	630	171	900	39
10	127	360	151	540	175	900	31
11	121	450	146	720	169	972	39
12	120	545	143	725	167	910	46
13	121	370	151	720	176	910	30
14	118	468	148	725	166	915	45

CONTROL - POST TRAINING

No.	Age (yrs.)	Ht. (cm.)	Wt. (kg.)	RHR (b/min.)	BP(Dis) (mm of Hg.)	BP(sys) (mm of Hg.)	EMG (µv/min.)	Ch. exp. (cm.)	Vc (l.)
1	19	167.6	65.8	81	79	120	5.1	6.6	3.1
2	24	165.1	57.4	76	78	119	8.1	5.3	3.4
3	23	160.0	60.3	78	80	118	5.6	6.9	3.2
4	27	162.7	62.0	78	80	119	4.7	4.7	3.4
5	26	167.4	56.9	80	84	122	4.2	4.6	3.1
6	18	161.2	57.7	77	80	122	5.7	5.8	3.2
7	29	163.8	57.6	80	81	122	5.3	5.4	3.2
8	28	167.6	54.2	78	83	119	4.6	5.3	3.1
9	28	156.9	67.3	79	77	120	5.7	5.0	3.2
10	28	170.8	49.4	79	80	119	5.9	5.0	3.3
11	20	170.8	49.4	79	77	120	4.7	5.3	3.2
12	20	163.8	62.5	79	83	119	3.8	5.3	3.1
13	29	162.5	60.2	80	79	118	8.3	5.1	3.3
14	17	173.7	56.5	78	79	119	4.2	5.6	3.2

CONTROL - POST TRAINING

No.	4th min. HR (b/min.)	Workload (kpm/min.)	8th min. HR (b/min.)	Workload (kpm/min.)	12th min. HR (b/min.)	Workload (kpm/min.)	PVo_2 max. (ml/kg/min.)
1	116	540	146	900	169	1260	38
2	121	550	152	910	173	1270	42
3	122	554	153	910	173	1260	36
4	118	550	149	910	171	1270	34
5	119	560	149	540	178	630	26
6	118	550	151	905	170	1090	46
7	128	270	155	360	175	540	26
8	122	450	150	630	171	900	39
9	126	360	149	540	175	900	39
10	121	450	146	720	169	972	39
11	118	545	142	725	167	910	46
12	122	570	152	720	176	910	30
13	117	468	148	725	166	915	45
14	122	540	148	905	174	1085	36

APPENDIX C

STATISTICAL TESTS

TWO-WAY ANOVA ON FRONTALIS EMG ACTIVITY

SUMMARY TABLE

Source	SS	DF	MS	F	P
Bet Sub	190.313	26			
A	76.63	1	76.63	16.85	0.00*
Sub W Group	113.661	25	4.547		
Within Sub	181.297	54			
B	86.682	2	43.341	73.595	0.00*
A x B	70.741	2	35.371	60.061	0.00*
B x Sub W Group	29.446	50	0.589		

*Significant at $p < 0.05$

TWO-WAY ANOVA ON DIASTOLIC BLOOD PRESSURE

SUMMARY TABLE

Source	SS	DF	MS	F	P
Bet Sub	652.75	26			
A	388.96	1	388.96	36.85	0.00*
Sub W Group	263.87	25	10.55		
Within Sub	617.37	54			
B	301.22	2	150.61	252.60	0.00*
A x B	308.28	2	154.14	258.51	0.00*
B x Sub W Group	29.813	50	0.596		

*Significant at $p < 0.05$

TWO-WAY ANOVA ON SYSTOLIC BLOOD PRESSURE

SUMMARY TABLE

Source	SS	DF	MS	F	P
Bet Sub	585.00	26			
A	485.33	1	485.33	121.33	0.00*
Sub W Group	100.00	25	4.00		
Within Sub	864.00	54			
B	397.70	2	198.85	144.09	0.00*
A x B	427.19	2	213.59	154.78	0.00*
B x Sub W Group	69.00	50	1.38		

*Significant at $p < 0.05$

TWO-WAY ANOVA ON RESTING HEART RATE

SUMMARY TABLE

Source	SS	DF	MS	F	P
Bet Sub	419.18	26			
A	325.39	1	325.39	86.42	0.00*
Sub W Group	94.12	25	3.76		
Within Sub	604.68	54			
B	320.50	2	160.25	262.16	0.00*
A x B	274.89	2	137.44	224.86	0.00*
B x Sub W Group	30.56	50	0.61		

*Significant at $p < 0.05$

TWO-WAY ANOVA ON CHEST EXPANSION

SUMMARY TABLE

Source	SS	DF	MS	F	P
Bet Sub	41.10	26			
A	15.86	1	15.86	15.71	0.00*
Sub W Group	25.23	25	1.00		
Within Sub	28.79	54			
B	17.48	2	8.74	174.74	0.00*
A x B	9.74	2	4.87	97.32	0.00*
B x Sub W Group	2.50	50	0.05		

*Significant at $p < 0.05$

TWO-WAY ANOVA ON VITAL CAPACITY

SUMMARY TABLE

Source	SS	DF	MS	F	P
Bet Sub	2.61	26			
A	1.70	1	1.70	46.83	0.00*
Sub W Group	0.91	25	0.03		
Within Sub	2.28	54			
B	1.21	2	0.60	517.84	0.00*
A x B	1.09	2	0.54	467.63	0.00*
B x Sub W Group	0.05	50	0.00		

*Significant at $p < 0.05$

TWO-WAY ANOVA ON EXERCISE HEART RATE - (4th min.)

SUMMARY TABLE

Source	SS	DF	MS	F	P
Bet Sub	1153.00	26			
A	256.14	1	256.14	7.14	0.01*
Sub W Group	896.00	25	35.84		
Within Sub	458.00	54			
B	272.00	2	136.07	174.46	0.00*
A x B	162.62	2	81.31	104.24	0.00*
B x Sub W Group	39.00	50	0.78		

*Significant at $p < 0.05$

TWO-WAY ANOVA ON EXERCISE HEART RATE - (8th min.)

SUMMARY TABLE

Source	SS	DF	MS	F	P
Bet Sub	895.00	26			
A	74.14	1	74.14	2.25	0.14
Sub W Group	822.00	25	32.88		
Within Sub	150.00	54			
B	69.09	2	34.54	95.96	0.00*
A x B	66.56	2	33.28	92.45	0.00*
B x Sub W Group	18.00	50	0.36		

*Significant at $p < 0.05$

TWO-WAY ANOVA ON EXERCISE HEART RATE - (12th min.)

SUMMARY TABLE

Source	SS	DF	MS	F	P
Bet Sub	1040.00	26			
A	10.95	1	10.95	0.26	0.61
Sub W Group	1032.00	25	41.28		
Within Sub	78.00	54			
B	35.38	2	17.69	55.29	0.00*
A x B	27.80	2	13.90	43.44	0.00*
B x Sub W Group	16.00	50	0.32		

*Significant at $p < 0.05$

TWO-WAY ANOVA ON PREDICTED Vo_2 MAXIMAL

SUMMARY TABLE

Source	SS	DF	MS	F	P
Bet Sub	3600.25	26			
A	37.54	1	37.54	0.26	0.61
Sub W Group	3562.68	25	142.50		
Within Sub	44.68	54			
B	18.90	2	9.45	57.29	0.00*
A x B	18.90	2	9.45	57.29	0.00*
B x Sub W Group	8.25	50	0.16		

*Significant at $p < 0.05$

F VALUES IN DIFFERENT COMPARISONS BY SCHEFFÉ METHOD

Comparison	EMG	RHR	BP(Dis)	BP(Sys)	Vital Capacity	Chest Expan.	4th min. HR	8th min. HR	12th min HR	PVo_2 max.
$G\text{-}1T_1$; $G\text{-}1T_3$	77.68*	344.00*	148.72*	350.72*	171.97*	64.68*	32.73*	11.57	4.27	0.72
$G\text{-}1T_1$; $G\text{-}1T_2$	11.41	75.11*	25.56*	59.69*	49.86*	40.60*	6.81	1.75	0.65	0.06
$G\text{-}1T_2$; $G\text{-}1T_3$	29.54*	97.65*	50.96*	121.03*	36.63*	1.36	9.67	3.94	1.57	0.35
$G\text{-}1T_1$; $G\text{-}2T_1$	0.01	0.62	0.03	0.53	0.00	0.12	0.07	0.00	1.15	0.01
$G\text{-}1T_2$; $G\text{-}2T_2$	7.65	58.08*	21.77*	56.27*	47.43*	28.12*	5.00	1.35	0.03	0.15
$G\text{-}1T_3$; $G\text{-}2T_3$	69.59*	303.34*	151.54*	349.68*	170.70*	43.42*	28.47*	10.94	2.58	1.01
$G\text{-}2T_1$; $G\text{-}2T_3$	0.27	0.537	0.01	0.14	0.105	1.36	0.61	0.00	0.00	0.00

$df_1 = 5$; $df_2 = 75$

$F_{tab} = 2.34$ ($p < 0.05$)

$F' = 2.34 \times 5 = 11.7$

*indicates significant ($p < 0.05$) difference.